A

P-Vector Module for z-Coordinate

The P-Vector module for z-coordinate was developed to compute absolute velocity from hydrographic data. This package is stored in the enclosed DVD-Rom and includes the makefile, source codes, plotting files (using Matlab), and a sample case. The sample case is located at a subdirectory called sample.dir. The test data set is the WOA climatological (T, S) fields for the North Atlantic Ocean. The gird resolution is set to be $1^\circ \times 1^\circ$ with 50 vertical levels (i.e., $n_x = 360, n_y = 180, n_z = 50$). The users may change for their own sakes. Chenwu Fan and Carlos Lozano helped in developing these codes.

A.1 Makefile

```
*******************************************************
SRC = whoi.f pvector.f pv.f pvpar.f userinp.f setmask.f matopen.f
matclose.f matotal.f matout.f

OBJS= $(SRC:.f=.o)
FFLAGS= -g

pvexe:    $(OBJS)
          f77 $(FFLAGS) -o pvexe $(OBJS)
pvector.o:    pstate.h pvector.f
          f77 $(FFLAGS) -c pvector.f
pv.o:    pstate.h pv.f
          f77 $(FFLAGS) -c pv.f
userinp.o:    pstate.h userinp.f
          f77 $(FFLAGS) -c userinp.f
whoi.o:    whoi.f
          f77 -g -c whoi.f
pvpar.o:    pstate.h pvpar.f
          f77 -g -c pvpar.f
setmask.o:    setmask.f
```

```
        f77 -g -c setmask.f matopen.o:    matopen.f
        f77 -g -c matopen.f matclose.o:    matclose.f
        f77 -g -c matclose.f
matotal.o:    matotal.f
        f77 -g -c matotal.f
matout.o:    pstate.h matout.f
        f77 $(FFLAGS) -c matout.f
```

A.2 Main Subdirectories

There are three major directories (*pvector*, *pvector_nc* and *pvector_rotation*) of the enclosed DVD-Rom for computing the absolute velocity in z-coordinate system. Among them, *pvector* and *pvector_nc* are used for (x, y)-axes aligning with (latitude, longitude); and *pvector_rotation* is used for (x, y)-axes not aligning with (latitude, longitude). The output of *pvector* is in the ASCII format. The output of *pvector_nc* is in the NetCDF format.

A.2.1 Subdirectory (pvector)

In this subdirectory, the input and output data are in the ASCII format. All the input and output files are arranged from west to east and norht to south. A sample data set (North Atlantic) is located in sample.dir. The following procedures are taken for running the sample case. The commands are listed using *italics*. Since all the data files are in the ASCII format, running this program is slow and needs large disk space.

(a) Create pvexe (executive file) in the pvectorcode director

$< make$

(b) Go to sample.dir and run pvexe

../pvexe $<$ *pv.inp*

for getting ASCII output data.

(c) Use the following matlab files to plot the output data.

uvlev.m - plot vertical velocity at different levels
tsrlev.m - plot temp, salt and density at different levels.

(d) Note that the input data order as:

West to east, top to bottom, north to south.

(e) Note that the output data order as:

Top to bottom, west to east, north to south.

A.2.2 Subdirectory (pvector_nc)

In this subdirectory, the input data are either in the ASCII or binary format, and the output in the NetCDF format. You must have NetCDF library in your system. If you do not have the NetCDF lib (library), you may download the netcdf library and the matlab-NetCDF interface from http://www.unidata.ucar.edu/software/netcdf/.

You may need to change the location of netcdf lib in the Makefile *mknc*. You can use *mknc* to compile the code in code_nc subdirectory. Two sample sets are located in the two subdirectories *Sample_NA_ASCII* and *Sample_NA_bin*. *Sample_NA_ASCII* contains input data in the ASCII format for the North Atlantic Ocean (similar to pvector/sample.dir) and one output file in the NetCDF format. *Sample_NA_bin* contains input data in the binary format for the North Atlantic Ocean and the output file in the NetCDF format. For the input file pvnc.inp, note that (a) ts (the first number on line 3): 1-ASCII data, 2-binary, (b) line 8: description of the netcdf file, and (c) line 9: the author.

A.2.3 Subdirectory (pvector_rotation)

When the horizontal coordinate system is not aligned with the longitude and latitude, you should use the subdirectory *pvector_rotation*. Different from *pvectorcode* and *pvector_nc*, use of *pvector_rotation* needs input of longitude and latitude data at each station. Line 2 of *pvxy.inp* is used for naming the 2D longitude and latitude data file. A sample set (named Sample_Arctic) is taken as an example with *Arctic Ocean.inp* as the control data file. The second line in that file shows the latitude, longitude, y, x, and name of data file. The data file can be either binary or ASCII data. The first number of line 3, 'ts' is the key word of the input data type:

topography data always in ASCII format.
temperature and salinity data:

ts	temperature and salinity data type
1	ascii data with order (mx,mz,my)
-1	ascii data with order (mz,mx,my)
2	binary data with order (mx,mz,my)
-2	binary data with order (mz,mx,my)

latitude, longitude, x, and y data:

```
      |ts|=1        ASCII data
      |ts|=2        binary data
   and with the order
                    lat(mx, my)
                    lon(mx, my)
                    x(mx, my)
                    y(mx, my)
```

It is noted that the output velocity (u, v) is in the directions of (x, y) axes not of longitude and latitude.

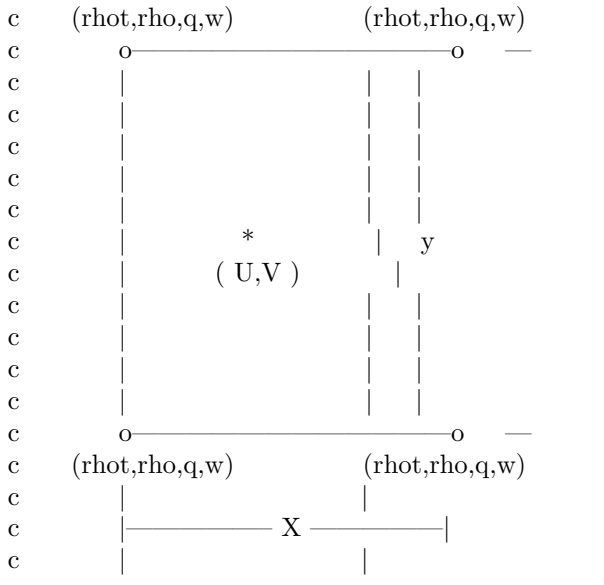
A.3 Major FORTRAN Programs

A.3.1 ASCII Format (pv.f)

This FORTRAN program is used for the coordinate system with the latitude as the x-axis and the longitude as the y-axis.

```
      program pv

c
c    — tempfile: temperature data file name
c    — saltfile: salitnity data file name
c    — topofile: topography data file name
c     The Grid desired as:
c
c      (rhot,rho,q)              (rhot,rho,q)
c          o————————*————————o      —
c          |       ( U,V )       |     |
c          |                     |     |
c          |                     |     |
c          |                     |     |
c          |                     |
c          *(w)                 (w)*     Z
c          |                     |
c          |                     |     |
c          |                     |     |
c          |                     |     |
c          |       ( U,V )       |     |
c          o————————*————————o      —
c      (rhot,rho,q)              (rhot,rho,q)
c          |                     |
c          |———————— X , Y ——————|
c          |                     |
c
```




```
c
c   Notes:
c   1. Setup.
c     For a given application the program is configured
c     internally by defining the parameters from the input data.
c     See pv.inp in the subdirectory smaple.dir.
c
c     mx,my,mz (the dimension for rho,rhot,q,temp,salt)
c     mx1=mx-1,my1=my-1,mz1=mz-1 (the dimension for u,v,w)
c
c     mx is the number of longitudinal points.
c     my is the number of latitudinal points.
c     mz is the number of depth points.
c
c     The following data should be filled up by user in the
c     subroutine pvpar
c
c     The point (1,1,1) is at the surface in the North West
c     edge of the grid.
c
c     spherical             [(0) dx=dy, (1) dx(j)=dy*cos(lat(j)]
c     global/regional       [(1) global, (0) regional]
c
c     grid_size (in degree)  [grid size spacing is uniform
c                       along longitude and latitude]
c
c     deep (1:mz)                [depth of z-levels (m).
c                         The origin is at the ocean surface
c                         and z is negative downwards.]
```

```
c       lat0                    [latitude (degree) at the NW corner]
c
c       lon0                    [longitude (degree) at the NW corner]
c
c       ktop                    [In the inversion procedure use
c                               only the levels [ktop:mz]]
c
c       ts                      read either TS or RHO RHOT
c          1                    read temp & salt from ascii data files
c          2                    read temp & salt from binary data files
c
c
c
c   2. Inputs:
c
c       stopog(mx,my)           topography for the subroutine read_topo
c                               see description in the subroutine header.
c
c       if(ts>=1):
c       temp(mx,my,mz)          temperature
c       salt(mx,my,mz)          salinity
c                               read in subroutine read_ts
c       if(ts==2):              Temperature and salinity show non-number.
c                               The bottom topography is reset at the same
c                               depth with T and S taking non-numbers.
c                               Read in the subroutine read_ts.
c       if(ts=0):
c       rho(mx,my,mx)           density
c       rhot(mx,my,mz)          potential density
c
c    3. Outputs:
c
c      u(mx1,my1,mz),v(mx1,my1,mz) absolute horizontal velocity
c      (m/s)
c      px(mx1,my1,mz),py(mx1,my1,mz) P-vector
c      invmask(mx1,my1)
c
c                          =-1        for inverse not being accomplished
c                          =0         for land
c                          >0         for inverse being accomplished
c
c      [1:invmask(i,j)]
c                          levels at which the absolute horizontal
c                          velocity is estimated.
c
```

```
c-----------------------------------------------------------------
--
c
c – volume grid size (user defined) ----------------------------
--
c
      include 'pstate.h'
      common /maxval6/ veval,vmax,ii,jj
      real veval(nz),vmax(6,nz)
      integer ii(6,nz),jj(6,nz)
c ---------------------------------------------------------------
      real temp(nx,2,nz),salt(nx,2,nz)
      real tempgb(nx,nz),saltgb(nx,nz)
c---------------------------------------------------------------
      integer j,spherical
      real lat0,lon0
      integer ts,ktop,sect,sect1,sect2
      real sims,pref,grid_size
      real radius,omega
      real f0
      real deep(nz)
      integer mx1,my1,stopog(nx,ny)
      real latmin
      integer iuvuni,iunpxy,iunrho,iuvunig,iunq
      integer k,ll
      character *30 topofile,tempfile,saltfile
c
      iuvuni=15
      iunpxy=26
      iunrho=17
      iuvunig=28
      iunq=19

      latmin=5.0
      zero=0.0
      one=1.0
      pi = 3.1415926535
      deg2rad = pi/180
c
c – cntrl parameters
c
      call pvpar(deep,grid_size,lon0,lat0,ktop,pref,ts,spherical,
     &     sims,topofile,tempfile,saltfile)
      my1=my-1
      mx1=mx-1
      if(global) mx1=mx

c – physical and numerical constants
      omega = 7.292e-5
      radius = 6.371e6
```

```
c-----------------------------------------------------------------------
c – grid spacing along latitude
c
      dy = grid_size*deg2rad*radius

      do j=1,my
         lat(j) = lat0 - (j-1)*grid_size
      enddo
c
c – grid spacing along longitude
c
      if (spherical.eq.0) then
       do j= 1, my
         dx(j) = dy
       enddo
      else

       do j= 1, my
         dx(j) = dy*cos(lat(j)*deg2rad)
       enddo
      endif
c
c – Coriolis (1/s)
c
      do j=1,my
       ff(j) = 2.*omega*sin(lat(j)*deg2rad)
       if(lat(j).lt.latmin .and. lat(j).ge.0.0)
     &    ff(j)=2.*omega*sin(latmin*deg2rad)
       if(lat(j).gt.-latmin .and. lat(j).le.0.0)
     &    ff(j)=-2.*omega*sin(latmin*deg2rad)
       enddo
       f0=0.5*(abs(ff(1))+abs(ff(my)))

       call read_topo(stopog,deep,ts,topofile,tempfile)

       call setmask(mx,my,istopog,rmask,invmask,global)

       do k=ktop,mz
        do ll=1,6
           vmax(i,k)=0.0
        enddo
        veval(k)=0.0
       enddo
       if(ts) then
        open(8,file=tempfile)
        open(9,file=saltfile)
       endif
```

```
      call matopen(iuvuni,iunpxy,iunrho,iuvunig,iunq)
      sect1=2
      sect2=1
      call userinp(stopog,deep,temp,salt,pref,ts,sect2,0)
      call pvector(stopog,deep,ktop,sims,sect1,sect2,f0,0)

      if(global) then
       do i=1,mx
          do k=1,mz
             tempgb(i,k)=temp(i,1,k)
             saltgb(i,k)=salt(i,1,k)
          enddo
       enddo
      endif

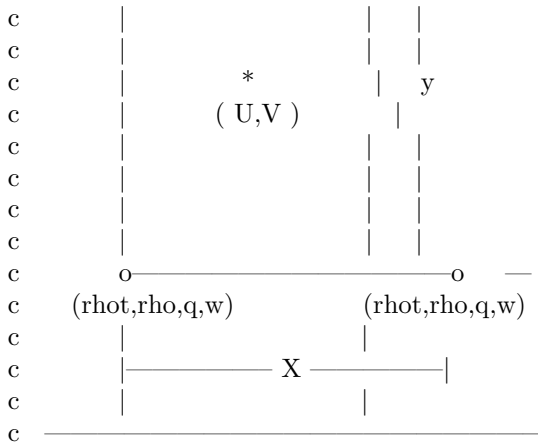
      do j=1,my1
       sect=sect2
       sect2=sect1
       sect1=sect
       call userinp(stopog,deep,temp,salt,pref,ts,sect2,j)
       call pvector(stopog,deep,ktop,sims,sect1,sect2,f0,j)
c
c – output
c
c
c – this output is designed for simple matlab inputs
c
        call matout(iuvuni,iunpxy,iunrho,iuvunig,iunq,
      &          temp,salt,sect2,f0)

      enddo
      close(8)
      if(ts) close(9)
      call matclose(iuvuni,iunpxy,iunrho,iuvunig,iunq)
      do k=ktop,mz
       veval(k)=veval(k)/(mx1*my1)
       print 77,k,-deep(k),veval(k)*100.0,(vmax(i,k)*100.0,i=1,6)
       print 88,(ii(i,k),jj(i,k),i=1,6)
      enddo
77     format(/i4,f8.0,7f8.2)
88     format(20x,6(2x,2i3))
      call matotal(mx1,my1,mz,istopog,rmask,invmask,deep,
      &           grid_size,lon0,lat0,ktop,pref,global)
      stop
      end
```

A.3.2 NetCDF Format (pvnc.f)

This FORTRAN program is used for the global coordinate system with the latitude as the x-axis and the longitude as the y-axis. The data format is in NetCDF.

```
**********************************************************
***
      program pvnc
c-------------------------------------------------------------
c
c-------------------------------------------------------------
c
c — tempfile: temperature data file name (binary data file)
c — saltfile: salitnity data file name (binary data file)
c — topofile: topography data file name
c — denfile: density data file name
c
c    The Grid desired as:
c
c       (rhot,rho,q)              (rhot,rho,q)
c            o-----------*-------------o      —
c            |         ( U,V )        |     |
c            |                        |     |
c            |                        |     |
c            |                        |     |
c            |                        |
c            *(w)                    (w)*      Z
c            |                        |
c            |                        |     |
c            |                        |     |
c            |                        |     |
c            |         ( U,V )        |     |
c            o-----------*-------------o      —
c       (rhot,rho,q)              (rhot,rho,q)
c            |                        |
c            |------------ X , Y -----------|
c            |                        |
c
c
c
c       (rhot,rho,q,w)                (rhot,rho,q,w)
c            o-----------------------------o    —
c            |                           |    |
c            |                           |    |
c            |                           |    |
```




```
c
c    Notes:
c    1. Setup.
c      For a given application the program is configured
c    internally by defining the parameters from the input data.
c
c    mx,my,mz (the dimension for rho,rhot,q,temp,salt)
c    mx1=mx-1,my1=my-1,mz1=mz-1 (the dimension for u,v,w)
c
c    mx is the number of longitudinal points.
c    my is the number of latitudinal points.
c    mz is the number of depth points.
c
c    The following data should be fill in by the user in the
c    subroutine pvpar
c
c    The point (1,1,1) is at the surface in the North West
c    edge of the grid.
c
c    spherical            [(0) dx=dy, (1) dx(j)=dy*cos(lat(j)]
c    global               [(1) global, (0) not global]
c
c    grid_size (in degrees) [The grid size spacing is uniform
c                  along longitude and latitude]
c
c    deep (1:mz)          [ The depth of the levels (m).
c                  The origin is at the ocean surface
c                  and z is negative downwards.]
c lat0               [ latitude (degrees) at NW corner. ]
c
c lon0               [ longitude (degrees) at NW corner]
c
```

```
c
c     ktop            [In the inversion procedure use
c                    only the levels [ktop:mz]]
c
c     ts              read either TS or RHO RHOT
c           1         read temp & salt from ascii data files
c           2         read temp & salt from binary data files
c
c

c      2. Inputs:
c
c      stopog(mx,my)       read in subroutine read_topo
c                          see description in subroutine header.
c
c      if(ts=1):
c      temp(mx,mz,my)       temperature
c      salt(mx,mz,my)       salinity
c                            read in subroutine read_ts
c      if(ts=0):
c      rho(mx,mz,my)       density
c      rhot(mx,mz,my)      potential density
c
c       3. Outputs: one NetCDF data format file
c
c-------------------------------------------------------------------
c
c      The binary output data file is named as pvoutbin.dat.
c      The structure of this file is given by
c      mx1,my1,mz,grid_size,lat0,lon0,ktop,pref,global
c      deep                                    (mz)
c      rho (j=my)                              (mx*mz)
c      rhot (j=my)                             (mx*mz)
c      stopog (j=my)                             (mx)
c      istopog (j=my)                            (mx)
c     *********
c     (the follow is my1 crosesection from j=my1 to 1, each section as:)
c      rmask                                    (mx1)
c      invmask                                   (mx1)
c      px                                      (mx1*mz)
c      py                                      (mx1*mz)
c      pz                                      (mx1*mz)
c      ug                                      (mx1*mz)
c      vg                                      (mx1*mz)
c      u                                      (mx1*mz)
```

```
c    v                                  (mx1*mz)
c    w                                  (mx1*mz)
c    rho                                (mx*mz)
c    rhot                               (mx*mz)
c    stopog                               (mx)
c    istopog                              (mx)
c   *********
c
c------- volume grid size (user defined) ------------------------
      include 'pstate.h'
      include 'netcdf.inc'

      common /maxval6/ veval,vmax,ii,jj
      real veval(nz),vmax(6,nz)
      integer ii(6,nz),jj(6,nz)
c-------------------------------------------------------
      real temp(nx,nz),salt(nx,nz)
c-------------------------------------------------------
      real deg2rad,pi,one
c-------------------------------------------------------
      integer j,spherical,mx1,my1
c     integer my_handler
      integer ts,ktop,sect,sect1,sect2
      real sims,pref,grid_size,lat0,lon0
      real radius,omega,f0
      real deep(nz), r1d(nx+ny)
      integer stopog(nx,ny), istw(3), ictw(3),
     &     dim2d(2), dim3d(3), ist2(2), ist3(3), ict2(2), ict3(3),
     &     dimr3d(3), ist3r(3), ict3r(3)
      integer*2 i1d(nx*(ny+nz))
      real latmin
      character*30 topofile,tempfile,saltfile
      character titl*80, author*30, created*9, ncflnm*30

      real*8 facu, facut, facw, fact, ofstst, ofstr

      data facu, facut, facw/1.0d-4,2.0d-2,1.0d-6/
      data fact, ofstst, ofstr/1.0d-3, 1.5d1, 1.28d3/

      data ist2,ist3,istw,ict2,ict3,ictw/16*1/
      data ist3r, ict3r/6*1/
c
      rlim=32760.0
      latmin=5.0
      zero=0.0
```

```
      one=1.0
      pi = 3.1415926535
      deg2rad = pi/180
c
c – cntrl parameters
c
      call pvpar(deep,grid_size,lon0,lat0,ktop,pref,ts,spherical,
     &     sims,topofile,tempfile,saltfile,titl,author,ncflnm)
      my1=my-1
      mx1=mx-1
      if(global) mx1=mx

c – physical and numerical constants
      omega = 7.292e-5
      radius = 6.371e6

c-----------------------------------------------------------------
c – gridspacing along latitude
c
      dy = grid_size*deg2rad*radius

      do j=1,my
        lat(j) = lat0 - (j-1)*grid_size
      enddo
c
c – grid spacing (m) along longitude
c
      if (spherical.eq.0) then
        do j= 1, my
          dx(j) = dy
        enddo
      else

        do j= 1, my
          dx(j) = dy*cos(lat(j)*deg2rad)
        enddo
      endif
c
c – Coriolis (1/s)
c
      do j=1,my
        ff(j) = 2.*omega*sin(lat(j)*deg2rad)
        if(lat(j).lt.latmin .and. lat(j).ge.0.0)
```

```
     &    ff(j)=2.*omega*sin(latmin*deg2rad)
          if(lat(j).gt.-latmin .and. lat(j).lt.0.0)
     &    ff(j)=-2.*omega*sin(latmin*deg2rad)
         enddo
         f0=0.5*(abs(ff(1))+abs(ff(my)))

         call read_topo(stopog,deep,ts,topofile,tempfile,saltfile)

         call setmask(mx,my,istopog,rmask,invmask,global)

         do k=ktop,mz
          do ll=1,6
           vmax(i,k)=0.0
          enddo
          veval(k)=0.0
         enddo

         call date(created)


         IRET = NF_CREATE(ncflnm,NF_CLOBBER,NCID)
         CALL ERRCHECK(IRET)

         IRET= F_PUT_ATT_TEXT(NCID,NF_GLOBAL,'title',80,titl)
         CALL ERRCHECK(IRET)
         IRET = NF_PUT_ATT_TEXT(NCID,NF_GLOBAL,'author',39,
        &          author//created)
         CALL ERRCHECK(IRET)
c
c     defind dimensions (lat, lon, lev)
c
         IRET = NF_DEF_DIM(NCID,'lat',my,IDJDIM)
         CALL ERRCHECK(IRET)
         IRET = NF_DEF_DIM(NCID,'latuv',my1,IDJUVDIM)
         CALL ERRCHECK(IRET)
         IRET = NF_DEF_DIM(NCID,'latw',my1-1,IDJWDIM)
         CALL ERRCHECK(IRET)
         IRET = NF_DEF_DIM(NCID,'lon',mx,IDIDIM)
         CALL ERRCHECK(IRET)
         IRET = NF_DEF_DIM(NCID,'lonuv',mx1,IDIUVDIM)
         CALL ERRCHECK(IRET)
         IRET = NF_DEF_DIM(NCID,'lonw',mx1-1,IDIWDIM)
         CALL ERRCHECK(IRET)
         IRET = NF_DEF_DIM(NCID,'lev',mz,IDKDIM)
         CALL ERRCHECK(IRET)
```

```
c
c     defined coordinate data (lat, lon, deep)
c
          IRET = NF_DEF_VAR(NCID,'lat',NF_float,1,
     &     IDJDIM,IDYCOORD)
          CALL ERRCHECK(IRET)
          IRET = NF_DEF_VAR(NCID,'latuv',NF_float,1,
     & IDJUVDIM,IDYUVCOORD)
          CALL ERRCHECK(IRET)
          IRET = NF_DEF_VAR(NCID,'latw',NF_float,1,IDJWDIM,
     & IDYWCOORD)
          CALL ERRCHECK(IRET)
          IRET = NF_DEF_VAR(NCID,'lon',NF_float,1,
     &IDIDIM,IDXCOORD)
          CALL ERRCHECK(IRET)
          IRET = NF_DEF_VAR(NCID,'lonuv',NF_float,1,
     &           IDIUVDIM,IDXUVCOORD)
          CALL ERRCHECK(IRET)
          IRET = NF_DEF_VAR(NCID,'lonw',NF_float,1,
     &           IDIWDIM,IDXWCOORD)
          CALL ERRCHECK(IRET)
          IRET = NF_DEF_VAR(NCID,'depth',NF_float,1,
     &           IDKDIM,IDZCOORD)
          CALL ERRCHECK(IRET)
          IRET = NF_PUT_ATT_TEXT(NCID,
     &           IDZCOORD,'units',6,'meters')
          CALL ERRCHECK(IRET)
          IRET = NF_PUT_ATT_TEXT(NCID,
     &            IDYCOORD,'long_name',28,
     &                  'Latitudinal Position for rho')
          CALL ERRCHECK(IRET)
          IRET = NF_PUT_ATT_TEXT(NCID,IDYUVCOORD,
     &'long_name',28,'Latitudinal Position for u,v')
          CALL ERRCHECK(IRET)
          IRET = NF_PUT_ATT_TEXT(NCID,IDYWCOORD,
     &'long_name',26, 'Latitudinal Position for w')
          CALL ERRCHECK(IRET)
          IRET = NF_PUT_ATT_TEXT(NCID,IDXCOORD,
     &'long_name',29, 'Longitudinal Position for rho')
          CALL ERRCHECK(IRET)
          IRET = NF_PUT_ATT_TEXT(NCID,IDXUVCOORD,
     &'long_name',29, 'Longitudinal Position for u,v')
          CALL ERRCHECK(IRET)
          IRET = NF_PUT_ATT_TEXT(NCID,IDXWCOORD,
     &'long_name',27, 'Longitudinal Position for w')
          CALL ERRCHECK(IRET)
          IRET = NF_PUT_ATT_TEXT(NCID,IDZCOORD,
     &'long_name',27,'Vertical Position for u,v,w')
          CALL ERRCHECK(IRET)
```

```
  dimr3d(1)=IDKDIM
  dimr3d(2)=IDIDIM
  dimr3d(3)=IDJDIM

  dim3d(1)=IDKDIM
  dim3d(2)=IDIUVDIM
  dim3d(3)=IDJUVDIM

  dim2d(1)=IDIUVDIM
  dim2d(2)=IDJUVDIM

  IRET = NF_DEF_VAR(NCID,'mask',NF_SHORT,2,
&          dim2d,IDMASK)
  CALL ERRCHECK(IRET)
  IRET = NF_DEF_VAR(NCID,'maskinv',NF_SHORT,2,
&          dim2d,IDMASKINV)
  CALL ERRCHECK(IRET)

  IRET = NF_DEF_VAR(NCID,'Temperature',NF_SHORT,3,
&          dimr3d,IDT)
  CALL ERRCHECK(IRET)
  IRET = NF_DEF_VAR(NCID,'Salinity',NF_SHORT,3,
&          dimr3d,IDS)
  CALL ERRCHECK(IRET)
  IRET = NF_DEF_VAR(NCID,'Density',NF_SHORT,3,
&          dimr3d,IDR)
  CALL ERRCHECK(IRET)
  IRET = NF_DEF_VAR(NCID,'Potential_Density',NF_SHORT,3,
&          dimr3d,IDRT)
  CALL ERRCHECK(IRET)
  IRET = NF_PUT_ATT_DOUBLE(NCID,IDT,'scale_factor',
&          NF_double,1,fact)
  CALL ERRCHECK(IRET)
  IRET = NF_PUT_ATT_DOUBLE(NCID,IDS,'scale_factor',
&          NF_double,1,fact)
  CALL ERRCHECK(IRET)
  IRET = NF_PUT_ATT_DOUBLE(NCID,IDR,'scale_factor',
&          NF_double,1,fact)
  CALL ERRCHECK(IRET)
  IRET = NF_PUT_ATT_DOUBLE(NCID,IDRT,'scale_factor',
&          NF_double,1,fact)
  CALL ERRCHECK(IRET)
  IRET = NF_PUT_ATT_DOUBLE(NCID,IDT,'add_offset',
```

```
     &           NF_double,1,ofstst)
        CALL ERRCHECK(IRET)
        IRET = NF_PUT_ATT_DOUBLE(NCID,IDS,'add_offset',
     &           NF_double,1,ofstst)
        CALL ERRCHECK(IRET)
        IRET = NF_PUT_ATT_DOUBLE(NCID,IDR,'add_offset',
     &           NF_double,1,ofstr)
        CALL ERRCHECK(IRET)
        IRET = NF_PUT_ATT_DOUBLE(NCID,IDRT,'add_offset',
     &           NF_double,1,ofstr)
        CALL ERRCHECK(IRET)

        IRET = NF_DEF_VAR(NCID,'u',NF_SHORT,3,dim3d,IDU)
        CALL ERRCHECK(IRET)
        IRET = NF_DEF_VAR(NCID,'v',NF_SHORT,3,dim3d,IDV)
        CALL ERRCHECK(IRET)
        dim3d(2)=IDIWDIM
        dim3d(3)=IDJWDIM
        IRET = NF_DEF_VAR(NCID,'w',NF_SHORT,3,dim3d,IDW)
        CALL ERRCHECK(IRET)

        dim2d(1)=IDIUVDIM
        dim2d(2)=IDJUVDIM
        IRET = NF_DEF_VAR(NCID,'utl',NF_SHORT,2,
     &            dim2d,IDUTL)
        CALL ERRCHECK(IRET)
        IRET = NF_DEF_VAR(NCID,'vtl',NF_SHORT,2,dim2d,
     &            IDVTL)
        CALL ERRCHECK(IRET)

        IRET = NF_PUT_ATT_TEXT(NCID,IDU,'long_name',14,
     &                  '3-D u-velosity')
        CALL ERRCHECK(IRET)
        IRET = NF_PUT_ATT_TEXT(NCID,IDU,'units',3,'m/s')
        CALL ERRCHECK(IRET)
        IRET = NF_PUT_ATT_DOUBLE(NCID,IDU,'scale_factor',
     &         NF_double,1,facu)
        CALL ERRCHECK(IRET)
        IRET = NF_PUT_ATT_TEXT(NCID,IDV,'long_name',14,
     &         '3-D v-velosity')
        CALL ERRCHECK(IRET)
```

```
  IRET = NF_PUT_ATT_TEXT(NCID,IDV,'units',3,'m/s')
  CALL ERRCHECK(IRET)
  IRET = NF_PUT_ATT_DOUBLE(NCID,IDV,'scale_factor',
&                    NF_double,1,facu)
  CALL ERRCHECK(IRET)
  IRET = NF_PUT_ATT_TEXT(NCID,IDW,'long_name',14,
&                    '3-D w-velosity')
  CALL ERRCHECK(IRET)
  IRET = NF_PUT_ATT_TEXT(NCID,IDW,'units',3,'m/s')
  CALL ERRCHECK(IRET)
  IRET = NF_PUT_ATT_DOUBLE(NCID,IDW,'scale_factor',
&                    NF_double,1,facw)
  CALL ERRCHECK(IRET)

  IRET = NF_PUT_ATT_TEXT(NCID,IDUTL,'long_name',32,
&                    'Vertically Integrated u-velosity')
  CALL ERRCHECK(IRET)
  IRET = NF_PUT_ATT_TEXT(NCID,IDUTL,'units',6,'m**2/s')
  CALL ERRCHECK(IRET)
  IRET = NF_PUT_ATT_DOUBLE(NCID,IDUTL,'scale_factor',
&                    NF_double,1,facut)
  CALL ERRCHECK(IRET)
  IRET = NF_PUT_ATT_TEXT(NCID,IDVTL,'long_name',32,
&                    'Vertically Integrated v-velosity')
  CALL ERRCHECK(IRET)
  IRET = NF_PUT_ATT_TEXT(NCID,IDVTL,'units',6,'m**2/s')
  CALL ERRCHECK(IRET)
  IRET = NF_PUT_ATT_DOUBLE(NCID,IDVTL,'scale_factor',
&                    NF_double,1,facut)
  CALL ERRCHECK(IRET)

  IRET = NF_ENDDEF(NCID)
  CALL ERRCHECK(IRET)

c
c     write coordinates
c
  r1d(1)=lon0
  do i=2,mx
     r1d(i)=r1d(i-1)+grid_size
  enddo
```

```
IRET = NF_PUT_VAR_real(NCID,IDXCOORD,r1d)
CALL ERRCHECK(IRET)
r1d(1)=lon0+0.5*grid_size
do i=2,mx1
 r1d(i)=r1d(i-1)+grid_size
enddo
IRET = NF_PUT_VAR_real(NCID,IDXUVCOORD,r1d)
CALL ERRCHECK(IRET)
do i=1,mx1-1
 r1d(i)=(r1d(i)+r1d(i+1))/2.0
enddo
IRET = NF_PUT_VAR_real(NCID,IDXWCOORD,r1d)
CALL ERRCHECK(IRET)
IRET = NF_PUT_VAR_real(NCID,IDYCOORD,lat)
CALL ERRCHECK(IRET)
do j=1,my1
 r1d(j)=(lat(j)+lat(j+1))/2.0
enddo
IRET = NF_PUT_VAR_real(NCID,IDYUVCOORD,r1d)
CALL ERRCHECK(IRET)
do j=1,my1-1
 r1d(j)=(r1d(j)+r1d(j+1))/2.0
enddo
IRET = NF_PUT_VAR_real(NCID,IDYWCOORD,r1d)
CALL ERRCHECK(IRET)
IRET = NF_PUT_VAR_real(NCID,IDZCOORD,deep)
CALL ERRCHECK(IRET)
do i=1,mx1
  do j=1,my1
    i1d(mx1*(j-1)+i)=rmask(i,j)
  enddo
enddo
IRET = NF_PUT_VAR_int2(NCID,IDMASK,i1d)
CALL ERRCHECK(IRET)

if(ts.ge.2) then
  open(8,file=tempfile,access='direct',recl=mx*mz)
  open(9,file=saltfile,access='direct',recl=mx*mz)
```

```
elseif(ts.ge.1) then
  open(8,file=tempfile)
  open(9,file=saltfile)
endif
sect1=2
sect2=1

call userinp(stopog,deep,temp,salt,pref,ts,sect2,0)
call pvector(stopog,deep,ktop,sims,sect1,sect2,f0,0)
ist3r(3)=1
ict3r(1)=mz
ict3r(2)=mx

do i=1,mx
  do k=1,mz
    uuu=temp(i,k)/fact+0.5-ofstst
    uuu=max(-rlim,uuu)
    uuu=min(rlim,uuu)
    i1d(mz*(i-1)+k)=uuu
  enddo
enddo
IRET = NF_PUT_VARA_int2(NCID,IDT,ist3r,ict3r,i1d)
CALL ERRCHECK(IRET)
do i=1,mx
  do k=1,mz
    uuu=salt(i,k)/fact+0.5-ofstst
    uuu=max(-rlim,uuu)
    uuu=min(rlim,uuu)
    i1d(mz*(i-1)+k)=uuu
  enddo
enddo
IRET = NF_PUT_VARA_int2(NCID,IDS,ist3r,ict3r,i1d)
CALL ERRCHECK(IRET)
do i=1,mx
  do k=1,mz
    uuu=rho(i,sect2,k)/factr+0.5-ofstr
    uuu=max(-rlim,uuu)
    uuu=min(rlim,uuu)
    i1d(mz*(i-1)+k)=uuu
  enddo
enddo
```

```
                IRET = NF_PUT_VARA_int2(NCID,IDR,ist3r,ict3r,i1d)
                CALL ERRCHECK(IRET)
                do i=1,mx
                   do k=1,mz
                     uuu=rhot(i,sect2,k)/factr+0.5-ofstr
                     uuu=max(-rlim,uuu)
                     uuu=min(rlim,uuu)
                     i1d(mz*(i-1)+k)=uuu
                   enddo
                enddo
                IRET = NF_PUT_VARA_int2(NCID,IDRT,ist3r,ict3r,i1d)
                CALL ERRCHECK(IRET)

                ict2(1)=mx1
                ict2(2)=1
                ict3(1)=mz
                ict3(2)=mx1
                ict3(3)=1
                ictw(1)=mz
                ictw(2)=mx1-1
                ictw(3)=1
                do j=1,my1
c                  print *,' j=',j
                   sect=sect2
                   sect2=sect1
                   sect1=sect
                   call userinp(stopog,deep,temp,salt,pref,ts,sect2,j)
                   call pvector(stopog,deep,ktop,sims,sect1,sect2,f0,j)
c
c - output
c
                   ist2(2)=j
                   ist3(3)=j
                   ist3r(3)=j+1
                   istw(3)=j-1
                   do i=1,mx
                      do k=1,mz
                       uuu=temp(i,k)/fact+0.5-ofstst
                       uuu=max(-rlim,uuu)
                       uuu=min(rlim,uuu)
                       i1d(mz*(i-1)+k)=uuu
                      enddo
                   enddo
```

```
IRET = NF_PUT_VARA_int2(NCID,IDT,ist3r,ict3r,i1d)
CALL ERRCHECK(IRET)
do i=1,mx
  do k=1,mz
    uuu=salt(i,k)/fact+0.5-ofstst
    uuu=max(-rlim,uuu)
    uuu=min(rlim,uuu)
    i1d(mz*(i-1)+k)=uuu
  enddo
enddo
IRET = NF_PUT_VARA_int2(NCID,IDS,ist3r,ict3r,i1d)
CALL ERRCHECK(IRET)
do i=1,mx
  do k=1,mz
    uuu=rho(i,sect2,k)/factr+0.5-ofstr
    uuu=max(-rlim,uuu)
    uuu=min(rlim,uuu)
    i1d(mz*(i-1)+k)=uuu
  enddo
enddo
IRET = NF_PUT_VARA_int2(NCID,IDR,ist3r,ict3r,i1d)
CALL ERRCHECK(IRET)
do i=1,mx
  do k=1,mz
    uuu=rhot(i,sect2,k)/factr+0.5-ofstr
    uuu=max(-rlim,uuu)
    uuu=min(rlim,uuu)
    i1d(mz*(i-1)+k)=uuu
  enddo
enddo
IRET = NF_PUT_VARA_int2(NCID,IDRT,ist3r,ict3r,i1d)
CALL ERRCHECK(IRET)

do i=1,mx1
  i1d(i)=invmask(i,j)
enddo

IRET = NF_PUT_VARA_int2(NCID,IDMASKINV,ist2,
&         ict2,i1d)
CALL ERRCHECK(IRET)
```

```
do i=1,mx1
  do k=1,mz
    uuu=u(i,sect2,k)/facu+0.5
    uuu=max(-rlim,uuu)
    uuu=min(rlim,uuu)
    i1d(mz*(i-1)+k)=uuu
  enddo
enddo
IRET = NF_PUT_VARA_int2(NCID,IDU,ist3,ict3,i1d)
CALL ERRCHECK(IRET)
do i=1,mx1
  do k=1,mz
    uuu=v(i,sect2,k)/facu+0.5
    uuu=max(-rlim,uuu)
    uuu=min(rlim,uuu)
    i1d(mz*(i-1)+k)=uuu
  enddo
enddo
IRET = NF_PUT_VARA_int2(NCID,IDV,ist3,ict3,i1d)
CALL ERRCHECK(IRET)
if(j.gt.1) then
do i=1,mx1-1
  do k=1,mz
    uuu=w(i,k)/facw+0.5
    uuu=max(-rlim,uuu)
    uuu=min(rlim,uuu)
    i1d(mz*(i-1)+k)=uuu
  enddo
enddo
IRET = NF_PUT_VARA_int2(NCID,IDW,istw,ictw,i1d)
CALL ERRCHECK(IRET)
endif

do i=1,mx1
 utt=0.0
 do k=2,invmask(i,j)
    utt=utt+(deep(k-1)-deep(k))*
```

```
&                    (u(i,sect2,k-1)+u(i,sect2,k))/2.0
        enddo
        utt=utt/facut+0.5
        utt=max(-rlim,utt)
        utt=min(rlim,utt)
        i1d(i)=utt
      enddo
      IRET = NF_PUT_VARA_int2(NCID,IDUTL,ist2,ict2,i1d)
      CALL ERRCHECK(IRET)
      do i=1,mx1
       utt=0.0
       do k=2,invmask(i,j)
        utt=utt+(deep(k-1)-deep(k))*
&                    (v(i,sect2,k-1)+v(i,sect2,k))/2.0
       enddo
       utt=utt/facut+0.5
       utt=max(-rlim,utt)
       utt=min(rlim,utt)
       i1d(i)=utt
      enddo
         IRET = NF_PUT_VARA_int2(NCID,IDVTL,ist2,ict2,i1d)
         CALL ERRCHECK(IRET)

      enddo
      close(8)
      close(9)

      IRET = NF_CLOSE(NCID)

      do k=ktop,mz
         veval(k)=veval(k)/(mx*my)
         print 77,k,-deep(k),veval(k)*100.0,(vmax(i,k)*100.0,i=1,6)
         print 88,(ii(i,k),jj(i,k),i=1,6)
      enddo
77       format(/i4,f8.0,7f8.2)
88       format(20x,6(2x,2i3))


      end
```

```
C=======================================
C
      SUBROUTINE ERRCHECK(IRET)
C*******************************************************
C
C       *ERRCHECK* ERROR HANDLER FOR GRAPHICAL
C       INTERFACE
C
C     AUTHOR - ROGER PROCTOR AND PATRICK LUYTEN
C
C     LAST UPDATE - 12 Jul 1999 @(COHERENS)netcdfint.f
C       8.4
C
C       DESCRIPTION - WRITE ERROR MESSAGE AND STOP
C       EXECUTION OF THE PROGRAM
C         IF AN ERROR OCCURS IN ONE OF THE netCDF
       ROUTINES
C
C      REFERENCE -
C
C      CALLING PROGRAM - CDF2D, CDF3D
C
C      EXTERNALS - NF_STRERROR
C
C*******************************************************
C
    INCLUDE 'netcdf.inc'

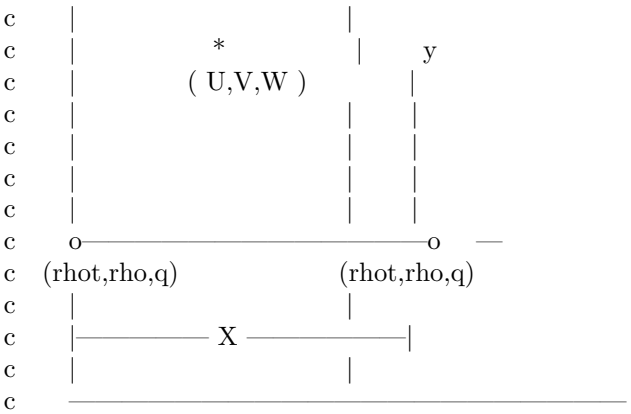
C
C   ARGUMENTS
C
    INTEGER IRET

    IF (IRET.NE.NF_NOERR) THEN
      WRITE (0,*) NF_STRERROR(IRET)
      STOP
    ENDIF

    RETURN
    END
```

A.3.3 Non-(Lat, Lon) Horizontal Coordinates (pvxync.f)

```
**********************************************************
**
 program pvxync
c-------------
c    This program is used for any rectangular horizontal coordinates.
c
c-------------------------------------------------------------
--
c      -- tempfile: name of temperature data file (binary data file)
c      -- saltfile: name of salitnity data file (binary data file)
c      -- ltlnfile: 2-D latitude & longitude data file name (binary)
c                              lon(mx,my), lat(mxmy), lonm(mx1,my1),
 latm(mx1,my1)
c
c    The Grid desired as:
c
c    (rhot,rho,q)                    (rhot,rho,q)
c       o-------------*---------------o      --
c       |          ( U,V,W )          |      |
c       |                        |    |
c       |                        |    |
c       |                        |
c       |                        |    Z
c       |                        |
c       |                        |    |
c       |                        |    |
c       |          ( U,V,W )          |      |
c       o-------------*---------------o      --
c    (rhot,rho,q)                  (rhot,rho,q)
c       |                           |
c       |------------ X, Y ---------------|
c       |                           |
c
c
c
c    (rhot,rho,q)                    (rhot,rho,q)
c       o-------------------------------o    --
c       |                           |      |
c       |                           |      |
c       |                           |      |
c       |                           |      |
```




```
c   Notes:
c   1. Setup.
c     For a given application the program is configured
c     internally by defining the parameters from the input data.
c
c     mx,my,mz (the dimension for rho,rhot,q,temp,salt)
c     mx1=mx-1,my1=my-1,mz1=mz-1 (the dimension for u,v)
c
c     mx is the number of longitudinal points.
c     my is the number of latitudinal points.
c     mz is the number of depth points.
c
c     The following data should be filled by the user for the
c     subroutine pvpar
c
c     The point (1,1,1) is at the surface in the North West
c     edge of the grid.
c
c     deep (1:mz)             [ The depth of the levels (m).
c                           The origin is at the ocean surface
c                           and z is negative downwards.]
c     lon&lat data file name    [ 2-D binary data (degrees)]
c
c
c     ktop                  [In the inversion procedure use
c                           only the levels [ktop:mz]]
c
c     ts              read either TS or RHO RHOT
c          1          ascii data with order (mx,mz,my)
c         -1          ascii data with order (mz,mx,my)
c          2          binary data with order (mx,mz,my)
c         -2          binary data with order (mz,mx,my)
c
```

```
c     2. Inputs:
c
c       lat(mx,my), lon(mx,my) 2-D data
c
c      if(ts>0):
c       temp(mx,mz,my)     temperature
c       salt(mx,mz,my)     salinity
c      if(ts<0):
c       temp(mz,mx,my)     temperature
c       salt(mz,mx,my)     salinity
c
c     3. Outputs:  one Netcdf data format file
c
c-----------------------------------------------------------------
c
c---- volume grid size (user defined) ---------------------------
      include 'pstate.h'
      include 'netcdf.inc'

      common /maxval6/ veval,vmax,ii,jj
      real veval(nz),vmax(6,nz)
      integer ii(6,nz),jj(6,nz)
c-----------------------------------------------------------------
      real temp(nx,2,nz),salt(nx,2,nz)
c-----------------------------------------------------------------
      real deg2rad,pi,one
c-----------------------------------------------------------------
      integer j,mx1,my1
      integer ts,ktop,sect,sect1,sect2
      real sims,pref
      real radius,omega,f0
      real deep(nz), r1d(nx*ny)
      integer ist3t(3), ict3t(3),
     &     dim2d(2), dim3d(3), ist2(2), ist3(3), ict2(2), ict3(3)
      integer*2 i1d(nx*(ny+nz))
      real latmin
      character*30 tempfile,saltfile,ltlnfile,pvoutfile
      character titl*80, author*30, created*9

      real*8 facu, facw, ofstu,
     &     facr, ofstr, fact, ofstt, facs, ofsts

      data facu, facw, ofstu/1.0d-4,1.0d-7,0.0d0/
      data facr, ofstr/1.0d-3, 28.0d0/
      data fact, ofstt/1.0d-3, 10.0d0/
```

```
      data facs, ofsts/1.0d-3, 20.0d0/

      data ist2,ist3,ist3t,ict2,ict3,ict3t/16*1/
c
      latmin=5.0
      zero=0.0
      one=1.0
      pi = 3.1415926535
      deg2rad = pi/180
c
c — cntrl parameters
c
      call pvpar(deep,ktop,pref,ts,sims,tempfile,saltfile,
     &          ltlnfile,pvoutfile,titl,author)
      my1=my-1
      mx1=mx-1

c — physical and numerical constants
      omega = 7.292e-5
      radius = 6.371e6

      deg2m=deg2rad*radius

c
c ——     read lat lon binary data
c
       if(abs(ts).eq.1) then
        open(18,file=ltlnfile)
         read(18,*) ((lat(i,j),i=1,mx),j=1,my)
         read(18,*) ((lon(i,j),i=1,mx),j=1,my)
         read(18,*) ((y(i,j),i=1,mx),j=1,my)
         read(18,*) ((x(i,j),i=1,mx),j=1,my)
        close(18)
       else
        open(18,file=ltlnfile,access='direct',recl=mx*my)
         read(18,rec=1) ((lat(i,j),i=1,mx),j=1,my)
         read(18,rec=2) ((lon(i,j),i=1,mx),j=1,my)
         read(18,rec=3) ((y(i,j),i=1,mx),j=1,my)
         read(18,rec=4) ((x(i,j),i=1,mx),j=1,my)
        close(18)
       endif
```

```
c
c     convert units from km to m
c
      do i=1,mx
       do j=1,my
        x(i,j)=x(i,j)*1000.0
        y(i,j)=y(i,j)*1000.0
       enddo
      enddo

c-------------------------------------------------------------
c -   gridspacing
c
      do i=1,mx1
       i1=i+1
       do j=1,my1
        j1=j+1
        lonm(i,j)=(lon(i,j)+lon(i1,j)+lon(i,j1)+lon(i1,j1))/4.0
        latm(i,j)=(lat(i,j)+lat(i1,j)+lat(i,j1)+lat(i1,j1))/4.0
        dx(i,j)=(x(i1,j)+x(i1,j1)-x(i,j)-x(i,j1))/2.0
        dy(i,j)=(y(i,j1)+y(i1,j1)-y(i,j)-y(i1,j))/2.0
       enddo
      enddo

 66    continue
c
c - Coriolis (1/s) at the corner of the cell
c
     do i=1,mx
       do j=1,my
         if(lat(i,j).lt.latmin .and. lat(i,j).ge.0.0) then
          ff(i,j)=2.*omega*sin(latmin*deg2rad)
         elseif(lat(i,j).gt.-latmin .and. lat(i,j).lt.0.0) then
          ff(i,j)=-2.*omega*sin(latmin*deg2rad)
         else
          ff(i,j)=2.*omega*sin(lat(i,j)*deg2rad)
         endif
       enddo
     enddo
c
c - Coriolis (1/s) at the center of the cell
c
```

```
      fmax=0.0
      fmin=100.0
      do i=1,mx1
       do j=1,my1
        if(latm(i,j).lt.latmin .and. latm(i,j).ge.0.0) then
         fm(i,j)=2.*omega*sin(latmin*deg2rad)
        elseif(latm(i,j).gt.-latmin .and. latm(i,j).lt.0.0) then
         fm(i,j)=-2.*omega*sin(latmin*deg2rad)
        else
         fm(i,j) = 2.*omega*sin(latm(i,j)*deg2rad)
        endif
         fmax=max(fmax,abs(fm(i,j)))
         fmin=min(fmin,abs(fm(i,j)))
        enddo
      enddo
      f0=0.5*(fmin,fmax)

      call read_topo(ts,tempfile,saltfile)

      call setmask(mx,my,istopog,rmask,invmask,global)

      do k=ktop,mz
       do ll=1,6
          vmax(i,k)=0.0
       enddo
       veval(k)=0.0
      enddo

      call date(created)

     print *,created
     IRET = NF_CREATE(pvoutfile,NF_CLOBBER,NCID)
     CALL ERRCHECK(IRET)
     IRET = F_PUT_ATT_TEXT(NCID,NF_GLOBAL,'title',80,titl)
     CALL ERRCHECK(IRET)
     IRET = NF_PUT_ATT_TEXT(NCID,NF_GLOBAL,'author',39,
    &                author//created)
     CALL ERRCHECK(IRET)


    c
    c     defind dimensions (lat, lon, lev)
    c
```

```
      IRET = NF_DEF_DIM(NCID,'lat',my,IDJTDIM)
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_DIM(NCID,'lon',mx,IDITDIM)
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_DIM(NCID,'latuvw',my1,IDJDIM)
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_DIM(NCID,'lonuvw',mx1,IDIDIM)
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_DIM(NCID,'lev',mz,IDKDIM)
      CALL ERRCHECK(IRET)
c
c     defined coordinate data (deep)
c


     IRET = NF_DEF_VAR(NCID,'depth',NF_float,1,
     &         IDKDIM,IDZCOORD)
     CALL ERRCHECK(IRET)
     IRET = NF_PUT_ATT_TEXT(NCID,IDZCOORD,
     &         'units',6,'meters')
     CALL ERRCHECK(IRET)
c
c     defined lon & lat as 2-D variables
c
      dim2d(1)=IDITDIM
      dim2d(2)=IDJTDIM
      IRET = NF_DEF_VAR(NCID,'lat',NF_float,2,dim2d,IDTLAT)
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_VAR(NCID,'lon',NF_float,2,dim2d,IDTLON)
      CALL ERRCHECK(IRET)
      dim2d(1)=IDIDIM
      dim2d(2)=IDJDIM
      IRET = NF_DEF_VAR(NCID,'latuvw',NF_float,2,
     &         dim2d,IDLAT)
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_VAR(NCID,'lonuvw',NF_float,2,
     &         dim2d,IDLON)
      CALL ERRCHECK(IRET)
c
c      defined 2-D & 3-D variables
c
```

```
   dim2d(1)=IDITDIM
   dim2d(2)=IDJTDIM
   IRET = NF_DEF_VAR(NCID,'itopo',NF_SHORT,2,
  &          dim2d,IDITOPO)
   CALL ERRCHECK(IRET)
   dim3d(1)=IDKDIM
   dim3d(2)=IDITDIM
   dim3d(3)=IDJTDIM
   IRET = NF_DEF_VAR(NCID,'temp',NF_SHORT,3,
  &        dim3d,IDTEMP)
   CALL ERRCHECK(IRET)
   IRET = NF_PUT_ATT_TEXT(NCID,IDTEMP,'units',8,
  &         'degree C')
   CALL ERRCHECK(IRET)
   IRET = NF_PUT_ATT_DOUBLE(NCID,IDTEMP,'scale_factor',
  &           NF_double,1,fact)
   CALL ERRCHECK(IRET)
   IRET = NF_PUT_ATT_DOUBLE(NCID,IDTEMP,'add_offset',
  &            NF_double,1,ofstt)
   CALL ERRCHECK(IRET)
   IRET = NF_DEF_VAR(NCID,'salt',NF_SHORT,3,
  &           dim3d,IDSALT)
   CALL ERRCHECK(IRET)
   IRET = NF_PUT_ATT_TEXT(NCID,IDSALT,'units',3,'psu')
   CALL ERRCHECK(IRET)
   IRET = NF_PUT_ATT_DOUBLE(NCID,IDSALT,'scale_factor',
  &            NF_double,1,facs)
   CALL ERRCHECK(IRET)
   IRET = NF_PUT_ATT_DOUBLE(NCID,IDSALT,'add_offset',
  &            NF_double,1,ofsts)
   CALL ERRCHECK(IRET)
   IRET = NF_DEF_VAR(NCID,'rhot',NF_SHORT,3,dim3d,
  &            IDRHOT)
   CALL ERRCHECK(IRET)
   IRET = F_PUT_ATT_TEXT(NCID,IDRHOT,'units',6,'kg/mˆ3')
   CALL ERRCHECK(IRET)
   IRET = F_PUT_ATT_DOUBLE(NCID,IDRHOT,'scale_factor',
  &            NF_double,1,facr)
   CALL ERRCHECK(IRET)
   IRET = NF_PUT_ATT_DOUBLE(NCID,IDRHOT,'add_offset',
   &                    NF_double,1,ofstr)
   CALL ERRCHECK(IRET)
```

```
      dim3d(2)=IDIDIM
      dim3d(3)=IDJDIM
      dim2d(1)=IDIDIM
      dim2d(2)=IDJDIM
      IRET = NF_DEF_VAR(NCID,'mask',NF_SHORT,2,
     &           dim2d,IDMASK)
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_VAR(NCID,'maskinv',NF_SHORT,2,
     &           dim2d,IDMASKINV)
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_VAR(NCID,'u',NF_SHORT,3,dim3d,IDU)
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_VAR(NCID,'v',NF_SHORT,3,dim3d,IDV)
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_VAR(NCID,'w',NF_SHORT,3,dim3d,IDW)
      CALL ERRCHECK(IRET)

      dim2d(1)=IDIDIM
      dim2d(2)=IDJDIM
      IRET = NF_DEF_VAR(NCID,'utl',NF_FLOAT,2,dim2d,IDUTL)
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_VAR(NCID,'vtl',NF_FLOAT,2,dim2d,IDVTL)
      CALL ERRCHECK(IRET)

      IRET = NF_PUT_ATT_TEXT(NCID,IDU,'long_name',14,
     &                  '3-D u-velosity')
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDU,'units',3,'m/s')
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_DOUBLE(NCID,IDU,'scale_factor',
     &                NF_double,1,facu)
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDV,'long_name',14,
     &                  '3-D v-velosity')
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDV,'units',3,'m/s')
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_DOUBLE(NCID,IDV,'scale_factor',
     &                NF_double,1,facu)
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDW,'long_name',14,
     &                  '3-D W-velosity')
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDW,'units',3,'m/s')
```

```
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_DOUBLE(NCID,IDW,'scale_factor',
     &                NF_double,1,facw)
      CALL ERRCHECK(IRET)

      IRET = NF_PUT_ATT_TEXT(NCID,IDUTL,'long_name',29,
     &                'Vertical Integrate u-velosity')
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDUTL,'units',6,'m**2/s')
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDVTL,'long_name',29,
     &                'Vertical Integrate v-velosity')
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDVTL,'units',6,'m**2/s')
      CALL ERRCHECK(IRET)

      IRET = NF_ENDDEF(NCID)
      CALL ERRCHECK(IRET)

c
c     write lon lat & depth data
c

      do j=1,my
        do i=1,mx
          r1d(i+mx*(j-1))=lon(i,j)
        enddo
      enddo
      IRET = NF_PUT_VAR_real(NCID,IDTLON,r1d)
      CALL ERRCHECK(IRET)

      do j=1,my
        do i=1,mx
          r1d(i+mx*(j-1))=lat(i,j)
        enddo
      enddo
      IRET = NF_PUT_VAR_real(NCID,IDTLAT,r1d)
      CALL ERRCHECK(IRET)
      do j=1,my
        do i=1,mx
          i1d(i+mx*(j-1))=istopog(i,j)
        enddo
      enddo
      IRET = NF_PUT_VAR_int2(NCID,IDITOPO,i1d)
      CALL ERRCHECK(IRET)
```

```
   do j=1,my1
    do i=1,mx1
      tt1=(lon(i,j)+lon(i+1,j))/2.0
      if(abs(tt1-lon(i,j)).gt.100.0) tt1=tt1+180.0
      tt2=(lon(i,j+1)+lon(i+1,j+1))/2.0
      if(abs(tt2-lon(i,j+1)).gt.100.0) tt2=tt2+180.0
      ttt=(tt1+tt2)/2.0
      if(abs(ttt-tt1).gt.100.0) ttt=ttt+180.0
      if(ttt.gt.180) ttt=ttt-360.0
      r1d(i+mx1*(j-1))=ttt
    enddo
   enddo
IRET = NF_PUT_VAR_real(NCID,IDLON,r1d)
CALL ERRCHECK(IRET)
do j=1,my1
 do i=1,mx1
    r1d(i+mx1*(j-1))=(lat(i,j)+lat(i,j+1)
* +lat(i+1,j)+lat(i+1,j+1))/4.0
 enddo
enddo
IRET = NF_PUT_VAR_real(NCID,IDLAT,r1d)
CALL ERRCHECK(IRET)
IRET = NF_PUT_VAR_real(NCID,IDZCOORD,deep)
CALL ERRCHECK(IRET)

do i=1,mx1
 do j=1,my1
    i1d(mx1*(j-1)+i)=rmask(i,j)
 enddo
enddo
IRET = NF_PUT_VAR_int2(NCID,IDMASK,i1d)
CALL ERRCHECK(IRET)
if(abs(ts).eq.2) then
 open(8,file=tempfile,access='direct',recl=mx*mz)
 open(9,file=saltfile,access='direct',recl=mx*mz)
elseif(abs(ts).eq.1) then
 open(8,file=tempfile)
 open(9,file=saltfile)
else
 print *,' Must input temp & salt (|ts|=1 or 2)!'
 stop
endif
sect1=2
sect2=1
```

```
call userinp(deep,temp,salt,pref,ts,sect2,0)
call pvector(deep,ktop,sims,sect1,sect2,f0,0)
ict3t(1)=mz
ict3t(2)=mx
ist3t(3)=1

do i=1,mx
 do k=1,mz
  r1d(mz*(i-1)+k)=temp(i,sect2,k)
 enddo
enddo
call real2int2(mx*mz,r1d,fact,ofstt,i1d)
IRET = NF_PUT_VARA_int2(NCID,IDTEMP,ist3t,ict3t,i1d)
CALL ERRCHECK(IRET)

do i=1,mx
 do k=1,mz
  r1d(mz*(i-1)+k)=salt(i,sect2,k)
 enddo
enddo
call real2int2(mx*mz,r1d,facs,ofsts,i1d)
IRET = NF_PUT_VARA_int2(NCID,IDSALT,ist3t,ict3t,i1d)
CALL ERRCHECK(IRET)

do i=1,mx
 do k=1,mz
  r1d(mz*(i-1)+k)=rhot(i,sect2,k)
 enddo
enddo
call real2int2(mx*mz,r1d,facr,ofstr,i1d)
IRET = NF_PUT_VARA_int2(NCID,IDRHOT,ist3t,ict3t,i1d)
CALL ERRCHECK(IRET)

ict2(1)=mx1
ict2(2)=1
ict3(1)=mz
ict3(2)=mx1
ict3(3)=1
do j=1,my1
c     print *,' j=',j
    sect=sect2
    sect2=sect1
    sect1=sect
    call userinp(deep,temp,salt,pref,ts,sect2,j)
    call pvector(deep,ktop,sims,sect1,sect2,f0,j)
```

```
c
c – output
c
      do i=1,mx1
        i1d(i)=invmask(i,j)
      enddo
      ist2(2)=j
      IRET = NF_PUT_VARA_int2(NCID,IDMASKINV,ist2,
     &       ict2,i1d)
      CALL ERRCHECK(IRET)

      ist3t(3)=j+1
      do i=1,mx
        do k=1,mz
          r1d(mz*(i-1)+k)=temp(i,sect2,k)
        enddo
      enddo
      call real2int2(mx*mz,r1d,fact,ofstt,i1d)
      IRET = NF_PUT_VARA_int2(NCID,IDTEMP,ist3t,ict3t,i1d)
      CALL ERRCHECK(IRET)
      do i=1,mx
        do k=1,mz
          r1d(mz*(i-1)+k)=salt(i,sect2,k)
        enddo
      enddo
      call real2int2(mx*mz,r1d,facs,ofsts,i1d)
      IRET = NF_PUT_VARA_int2(NCID,IDSALT,ist3t,ict3t,i1d)
      CALL ERRCHECK(IRET)

      do i=1,mx
        do k=1,mz
          r1d(mz*(i-1)+k)=rhot(i,sect2,k)
        enddo
      enddo
      call real2int2(mx*mz,r1d,facr,ofstr,i1d)
      IRET = NF_PUT_VARA_int2(NCID,IDRHOT,ist3t,ict3t,i1d)
      CALL ERRCHECK(IRET)
      ist3(3)=j

      do i=1,mx1
        do k=1,mz
          r1d(mz*(i-1)+k)=u(i,k)
        enddo
      enddo
```

```
    call real2int2(mx1*mz,r1d,facu,ofstu,i1d)
    IRET = NF_PUT_VARA_int2(NCID,IDU,ist3,ict3,i1d)
    CALL ERRCHECK(IRET)

    do i=1,mx1
      do k=1,mz
        r1d(mz*(i-1)+k)=v(i,k)
      enddo
    enddo
    call real2int2(mx1*mz,r1d,facu,ofstu,i1d)
    IRET = NF_PUT_VARA_int2(NCID,IDV,ist3,ict3,i1d)
    CALL ERRCHECK(IRET)

    do i=1,mx1
      do k=1,mz
        r1d(mz*(i-1)+k)=w(i,k)
      enddo
    enddo
    call real2int2(mx1*mz,r1d,facw,ofstu,i1d)
    IRET = NF_PUT_VARA_int2(NCID,IDW,ist3,ict3,i1d)
    CALL ERRCHECK(IRET)
    do i=1,mx1
      r1d(i)=0.0
      do k=2,invmask(i,j)
        r1d(i)=r1d(i)+(deep(k-1)-deep(k))*
&           (u(i,k-1)+u(i,k))/2.0
      enddo
    enddo
    IRET = NF_PUT_VARA_real(NCID,IDUTL,ist2,ict2,r1d)
    CALL ERRCHECK(IRET)
    do i=1,mx1
      r1d(i)=0.0
      do k=2,invmask(i,j)
        r1d(i)=r1d(i)+(deep(k-1)-deep(k))*
&           (v(i,k-1)+v(i,k))/2.0
      enddo
    enddo
    IRET = NF_PUT_VARA_real(NCID,IDVTL,ist2,ict2,r1d)
    CALL ERRCHECK(IRET)

    enddo
    close(8)
    close(9)

    IRET = NF_CLOSE(NCID)

    do k=ktop,mz
      veval(k)=veval(k)/(mx*my)
```

```
 print 77,k,-deep(k),veval(k)*100.0,(vmax(i,k)*100.0,i=1,6)
 print 88,(ii(i,k),jj(i,k),i=1,6)
enddo
77      format(/i4,f8.0,7f8.2)
88      format(20x,6(2x,2i3))
 end
```

A.4 Include File (pstate.h)

```
c-----------------------------------------------------------------
      integer nx,ny,nz
      parameter (nx=360,ny=180,nz=50)
      common /pstate/rho,rhot,
     &           q,px,py,pz,qx,qy,qz,u,v,w,rhox,rhoy,
     &           rhotx,rhoty,rhotz,ug,vg,fac_scale,power,
     &           lat,ff,zero,one,pi,deg2rad,
     &           dx,dy,
     &           mx,my,mz,global,istopog,
     &           qmask,rmask,invmask

      real rho(nx,2,nz),rhot(nx,2,nz)
      real q(nx,2,nz)
      real px(nx,nz),py(nx,nz),pz(nx,nz)
      real qx(nx,nz),qy(nx,nz),qz(nx,nz)
      real u(nx,2,nz),v(nx,2,nz),w(nx,nz)
      real fac_scale,power
      real rhox(nx,nz),rhoy(nx,nz)
      real rhotx(nx,nz),rhoty(nx,nz),rhotz(nx,nz)
      real ug(nx,nz),vg(nx,nz)
      real ff(ny),lat(ny)
      real dx(ny),dy,one,zero,pi,deg2rad
      integer mx,my,mz,global
      integer istopog(nx,ny),rmask(nx,ny),invmask(nx,ny)
```

A.5 Data Input

The *subroutine userinp* is used to read (T, S, H) data into the P-vector inverse model. Here, H is the water depth.

```
*************************************************
   subroutine userinp(stopog,deep,temp,salt,pref,ts,sect,j)
   include 'pstate.h'
   integer i,j,k,ts,sect
   real temp(nx,2,nz),salt(nx,2,nz),deep(nz),pref
   real pressure,saltd,tempd,dum,svan,tempt,theta
   integer stopog(nx,ny)
```

```
c
c — clear local array
c
   do i=1,mx
      do k=1,mz
         rho(i,sect,k)=0.0
         rhot(i,sect,k)=0.0
      enddo
   enddo
c — ts is a keyword, if ts=1 means input temp ans salt,
c    otherwise input is rho
c
c ——— (User dependent inputs) ——————————
c
c
c — read stopog(mx,my)
c — stopog(i,j) is the last 'wet' level in the column (i,j)
c    iunit=10
c    call read_topo(stopog,deep,iunit)
c
c — read temperature and salinity
c
     read(8,*) ((temp(i,sect,k),i=1,mx),k=1,mz)
     read(9,*) ((salt(i,sect,k),i=1,mx),k=1,mz)
c———————— (end of user dependent inputs)————————
c
c — compute in situ density RHO and potential density RHOT
c
c    Note: To minimize roundoff use sig=rho-1000.
c    svan is UNESCO (Fofonoff) subroutine.

    do i=1, mx
     do k=1, istopog(i,j+1)
       pressure= abs(deep(k))
       saltd=salt(i,sect,k)
       tempd=temp(i,sect,k)
       dum = svan(saltd,tempd,pressure,rho(i,sect,k) )
       if (pref .lt.0) then
       rhot(i,sect,k)=rho(i,sect,k)
       else
         tempt= theta(saltd,tempd,pressure,pref)
         dum = svan(saltd,tempt,pref,rhot(i,sect,k))
```

```
            endif
          enddo
        enddo
      return
     end

      subroutine read_topo(stopog,deep,iunit,ts,topofile,
     &                     saltfile)
c ------------------------------
c     USER supplied subroutine to:
c
c     read stopog(1:mx,1:my) where
c     stopog(i,j) is the deepth and
c     istopog(i,j) is the last wet point at (i,j);
c     that is, at (i,j) the levels istopog(i,j)+1,..,mz
c     if any, are land points.
c ------------------------------
      include 'pstate.h'
      integer iunit,i,j,k,ts
      integer stopog(nx,ny),minto
      real deep(nz)
      character*30 topofile,saltfile
c-----------------------------------------------------------
open(iunit,file=topofile,form='formatted')
do j=1,my
      read(iunit,*) (stopog(i,j),i=1,mx)
enddo
close(iunit)
minto=1000
do i=1,mx
      do j=1,my
         minto=min(minto,stopog(i,j))
      enddo
enddo
if(minto.lt.-2) then
      do i=1,mx
         do j=1,my
            istopog(i,j)=0
            do k=1,mz
               if(deep(k).ge.stopog(i,j)) istopog(i,j)=k
            enddo
         enddo
      enddo
```

```
    else
      do i=1,mx
        do j=1,my
          istopog(i,j)=stopog(i,j)
          stopog(i,j)=deep(istopog(i,j))
        enddo
        enddo
    endif
    if(ts.eq.2) then
      open(iunit,file=saltfile)
        do j=1,my
          read(iunit,*) ((w(i,k),i=1,mx),k=1,mz)
          do i=1,mx
            minto=0
            do k=1,mz
              if(w(i,k).gt.-80.0) minto=k
            enddo
              istopog(i,j)=min(istopog(i,j),minto)
          enddo
        enddo
      close(iunit)
    endif

    return
    end
```

A.6 Equation of State (whoi.f)

The program *whoi.f* is used to calculate density from (T, S).

```
**************************************************
C Program whoi.f
C JUNE 24 1982
      REAL FUNCTION SVAN(S,T,P0,SIGMA)
C MODIFIED RCM
C **************************************************
C SPECIFIC VOLUME ANOMALY (STERIC ANOMALY) BASED ON
       1980 EQUATION
C OF STATE FOR SEAWATER AND 1978 PRACTICAL SALINITY
       SCALE.
C REFERENCES
C MILLERO, ET AL (1980) DEEP-SEA RES.,27A,255-264
C MILLERO & POISSON 1981,DEEP-SEA RES.,28A PP 625-629.
C BOTH ABOVE REFERENCES ARE ALSO FOUND IN UNESCO
       REPORT 38 (1981)
```

```
C      UNITS:
C     PRESSURE    P0    DECIBARS
C     TEMPERATURE    T    DEG    CELSIUS (IPTS-68)
C     SALINITY    S    PSU    (IPSS-78)
C     SPEC. VOL. ANA. SVAN    M**3/KG *1.0E-8
C     DENSITY ANA.    SIGMA    KG/M**3
C     CHECK VALUE: SVAN = 981.30190 M**3/KG FOR S = 40 PSU,
C     T = 40 DEG C, P0= 10000 DECIBARS.
C ************************************************************
C ****************************
C CHECK VALUE: SIGMA = 59.82037 KG/M**3 FOR S = 40 PSU,
C T = 40 DEG C, P0= 10000 DECIBARS.
C ********************************************************
      REAL P,T,S,SIG,SR,R1,R2,R3,R4
      REAL A,B,C,D,E,A1,B1,AW,BW,K,K0,KW,K35
C EQUIV
      EQUIVALENCE (E,D,B1),(BW,B,R3),(C,A1,R2)
      EQUIVALENCE (AW,A,R1),(KW,K0,K)
C ********************
C DATA
      DATA R3500,R4/1028.1063,4.8314E-4/
      DATA DR350/28.106331/
C    R4 IS REFERED TO AS C IN MILLERO & POISSON 1981
C CONVERT PRESSURE TO BARS AND TAKE SQUARE
ROOT SALINITY.
      P=P0/10.
      SR = SQRT(ABS(S))
C ********************************************************
C PURE WATER DENSITY AT ATMOSPHERIC PRESSURE
C    BIGG P.H.,(1967) BR. J. APPLIED PHYSICS 8 PP 521-537.
C
   R1 = ((((6.536332E-9*T-1.120083E-6)*T+1.001685E-4)*T
   X-9.095290E-3)*T+6.793952E-2)*T-28.263737
C SEAWATER DENSITY ATM PRESS.
C COEFFICIENTS INVOLVING SALINITY
C R2 = A IN NOTATION OF MILLERO & POISSON 1981
   R2 = (((5.3875E-9*T-8.2467E-7)*T+7.6438E-5)*T-4.0899E-3)*T
   X+8.24493E-1
C R3 = B IN NOTATION OF MILLERO & POISSON 1981
   R3 = (-1.6546E-6*T+1.0227E-4)*T-5.72466E-3
C INTERNATIONAL ONE-ATMOSPHERE EQUATION OF STATE OF
SEAWATER
   SIG = (R4*S + R3*SR + R2)*S + R1
C SPECIFIC VOLUME AT ATMOSPHERIC PRESSURE
   V350P = 1.0/R3500
   SVA = -SIG*V350P/(R3500+SIG)
   SIGMA=DR350-(SVA/(V350P*(V350P+SVA)))
```

```
C SCALE SPECIFIC VOL. ANAMOLY TO NORMALLY REPORTED
   UNITS
    SVAN=SVA*1.0E+8
    IF(P.EQ.0.0) RETURN
C ***************************************************************
C ****** NEW HIGH PRESSURE EQUATION OF STATE FOR
            SEAWATER ********
C ***************************************************************
C COMPUTE COMPRESSION TERMS
    E = (9.1697E-10*T+2.0816E-8)*T-9.9348E-7
    BW = (5.2787E-8*T-6.12293E-6)*T+3.47718E-5
    B = BW + E*S
C
    D = 1.91075E-4
    C = (-1.6078E-6*T-1.0981E-5)*T+2.2838E-3
    AW = ((-5.77905E-7*T+1.16092E-4)*T+1.43713E-3)*T
    X-0.1194975
    A = (D*SR + C)*S + AW
C
    B1 = (-5.3009E-4*T+1.6483E-2)*T+7.944E-2
    A1 = ((-6.1670E-5*T+1.09987E-2)*T-0.603459)*T+54.6746
    KW = (((-5.155288E-5*T+1.360477E-2)*T-2.327105)*T
    X+148.4206)*T-1930.06
    K0 = (B1*SR + A1)*S + KW
C EVALUATE PRESSURE POLYNOMIAL
C ***********************************************
C   K EQUALS THE SECANT BULK MODULUS OF SEAWATER
C   DK=K(S,T,P)-K(35,0,P)
C K35=K(35,0,P)
C ***********************************************
    DK = (B*P + A)*P + K0
    K35 = (5.03217E-5*P+3.359406)*P+21582.27
    GAM=P/K35
    PK = 1.0 - GAM
    SVA = SVA*PK + (V350P+SVA)*P*DK/(K35*(K35+DK))
C SCALE SPECIFIC VOL. ANAMOLY TO NORMALLY REPORTED UNITS
    SVAN=SVA*1.0E+8
    V350P = V350P*PK
C ***************************************************
C COMPUTE DENSITY ANAMOLY WITH RESPECT TO 1000.0 KG/M**3
C 1) DR350: DENSITY ANAMOLY AT 35 PSU 0 DEG. C & ATMOSPHERIC
      PRES.
C 2) DR35P: DENSITY ANAMOLY 35 PSU 0 DEG. C , WITH PRES.
      VARIATION
```

```
C 3) DVAN : DENSITY ANAMOLY VARIATIONS INVOLVING SPECFIC
     VOL. ANAMOLY
C *****************************************************************
C CHECK VALUE: SIGMA = 59.82037 KG/M**3 FOR S = 40 PSU,
C T = 40 DEG C, P0= 10000 DECIBARS.
C *****************************************************
      D350=GAM/PK
      DR35P=R3500*D350
      DVAN=SVA/(V350P*(V350P+SVA))
      SIGMA=DR350+DR35P-DVAN
      RETURN
      END
C SAL78 FCN ********** OCT 24 1979 *******
      REAL FUNCTION SAL78(CND,T,P,C1535,M)
C ***************************************
C
C FUNCTION TO CONVERT CONDUCTIVITY TO SALINITY (M = 0)
  OR
C SALINITY TO CONDUCTIVITY (M = 1,CND = SAL)
C*****************************************************************
C  REFERENCES: ALSO LOCATED IN UNESCO REPORT # 37 1981
C PRACTICAL SALINITY SCALE 1978: E.L. LEWIS IEEE OCEAN
  ENG. JAN. 1980
C CONDUCTIVITY AT S=35.,T=15,P=0: CULKIN & SMITH IEEE
  OCEAN ENG. 1980.
C *****************************************************************
C C1535 = 42.914 MMHO/CM ADOPTED VALUE OF ABSOLUTE
  CONDUCTIVITY AT
C SALINITY 35 PSU AND TEMPERATURE 15 DEG CELSIUS
  (IPTS-68) FOR
C ATMOSPHERIC (0 DECIBARS) PRESSURE
C SAL78: RETURNS ZERO FOR CONDUCTIVITY: < 0.0005 MMHO/CM.
C SAL78: RETURNS ZERO FOR SALINITY: < 0.02    PSU
C UNITS:
C     PRESSURE      P       DECIBARS
C     TEMPERATURE     T       DEG CELSIUS (IPTS-68)
C     CONDUCTIVITY    CND     MMHO/CM.
C     SALINITY        SAL78     PSU (IPSS-78)
C CHECKVALUE: FOR C1535=42.914 MMHO/CM
C     SAL78 = 81.02555 :S=40 PSU,T=40 DEG C,P=10000
      DECIBARS:M=0
```

```
C     SAL78 = 40.00000 FOR G = 81.02555,T=40 DEG C,P=10000
      DECIBARS:M=1
C N FOFONOFF, REVISED JUNE 8 1982
C C ***********************************************************
C INTERNAL FUNCTIONS
C ************************************************************
C PRACTICAL SALINITY SCALE 1978 DEFINITION WITH
TEMPERATURE CORRECTION
C XT=T-15.0 : XR=SQRT(RT)
  SAL(XR,XT) =((((2.7081*XR-7.0261)*XR+14.0941)*XR+25.3851)*XR
  X-0.1692)* XR+0.0080
C TEMPERATURE CORRECTION TO 1978 PRACTICAL SALINITY
  SCALE: (XT=T-15.0)
  X  +(XT/(1.0+0.0162*XT))*(((((-0.0144*XR+
  X  0.0636)*XR-0.0375)*XR-0.0066)*XR-0.0056)*XR+0.0005)
C DSAL(XR,XT) EXPLICIT FUNCTION FOR DERIVATIVE
  OF SAL(XR,XT)
C WITH RESPECT TO CONDUCTIVITY RATIO XR.
  DSAL(XR,XT) =((((13.5405*XR-28.1044)*XR+42.2823)*XR+50.7702)*XR
  X  -0.1692)+(XT/(1.0+0.0162*XT))*((((-0.0720*XR+0.2544)*XR
  X  -0.1125)*XR-0.0132)*XR-0.0056)
C FUNCTION RT35 : CONDUCTIVITY RATIO C(35,T,0)/C(35,15,0)
  VARIATION
C WITH TEMPERATURE.
  RT35(XT) = (((1.0031E-9*XT-6.9698E-7)*XT+1.104259E-4)*XT
  X   + 2.00564E-2)*XT + 0.6766097
C POLYNOMIALS OF RP: CONDUCTIVITY RATIO C(S,T,P)/C(S,T,0)
  PRESSURE
C VARIATION: COEFFICIENTS PRESSURE SET FOR UNITS OF
  DECIBARS!!
C C(XP) POLYNOMIAL CORRESPONDS TO A1-A3 CONSTANTS:
  LEWIS 1980
   C(XP) = ((3.989E-15*XP-6.370E-10)*XP+2.070E-5)*XP
   B(XT) = (4.464E-4*XT+3.426E-2)*XT + 1.0
C A(XT) POLYNOMIAL CORRESPONDS TO B3 & B4 CONSTANTS:
  LEWIS 1980
  pcA(XT) = -3.107E-3*XT + 0.4215
C************************************************************
C TEST FOR ZERO OR NEGATIVE ABSOLUTE CONDUCTIVITY
C SET DEFAULT CONDUCTIVITY VALUE AT S=35, T=15 &
ATMOSPHERIC PRES.
  IF(C1535.LE.0.0) C1535=42.914
C ********************************
```

```
C ZERO SALINITY/CONDUCTIVITY TRAP
  SAL78=0.0
  IF((M.EQ.0).AND.(CND.LE.5E-4)) RETURN
  IF((M.EQ.1).AND.(CND.LE.0.02)) RETURN
C *********************************************
  DT = T - 15.0
C SELECT BRANCH FOR SALINITY (M=0) OR CONDUCTIVITY
  (M=1)
  IF(M.EQ.1) GO TO 10
C *********************************************
C CONVERT CONDUCTIVITY TO SALINITY
  R = CND/C1535
  RT = R/(RT35(T)*(1.0 + C(P)/(B(T) + A(T)*R)))
  RT = SQRT(ABS(RT))
  SAL78 = SAL(RT,DT)
  RETURN
C ********* END OF CONDUCTIVITY TO SALINITY SECTION ***
C *****************************************************
C INVERT SALINITY TO CONDUCTIVITY BY THE
C NEWTON-RAPHSON ITERATIVE METHOD.
C *****************************************************
C FIRST APPROXIMATION
  RT = SQRT(CND/35.0)
    SI = SAL(RT,DT)
    N = 0
C
C ITERATION LOOP BEGINS HERE WITH A MAXIMUM OF
     10 CYCLES
C
  RT = RT + (CND - SI)/DSAL(RT,DT)
    SI = SAL(RT,DT)
    N = N + 1
    DELS = ABS(SI - CND)
    IF((DELS.GT.1.0E-4).AND.(N.LT.10))GO TO 15
C
C ***************************END OF ITERATION LOOP ********
C
C COMPUTE CONDUCTIVITY RATIO
    RTT = RT35(T)*RT*RT
    AT = A(T)
    BT = B(T)
    CP = C(P)
    CP = RTT*(CP + BT)
    BT = BT - RTT*AT
```

```
C
C SOLVE QUADRATIC EQUATION FOR R: R=RT35*RT*(1+C/AR+B)
C
      R = SQRT(ABS(BT*BT + 4.0*AT*CP)) - BT
C CONDUCTIVITY RETURN
      SAL78 = 0.5*C1535*R/AT
      RETURN
      END
C DEPTH FCN ***** OCT 7 1980 *****
      REAL FUNCTION DEPTH(P0,LAT)
C ******************************
C DEPTH IN METERS FROM PRESSURE IN BARS USING
C SAUNDERS AND FOFONOFF'S METHOD.
C DEEP-SEA RES., 1976,23,109-111.
C FORMULA REFITTED FOR 1980 EQUATION OF STATE
C UNITS:
C      PRESSURE       P0       DECIBARS
C      DEPTH          DEPTH    METERS
C CHECKVALUE: DEPTH = 9712.654 M FOR P=10000 DECIBARS,
   LATITUDE=30 DEG
C     ABOVE FOR STANDARD OCEAN: T=0 DEG. CELSUIS ; S=35 PSU
C
   REAL LAT
C
X = SIN(LAT/57.29578)
C   SCALE PRESSURE TO BARS
P=P0/10.
C*************************
X = X*X
C GR= GRAVITY VARIATION WITH LATITUDE: ANON (1970)
   BULLETIN GEODESIQUE
      GR = 9.780318*(1.0+(5.2788E-3+2.36E-5*X)*X) + 1.092E-5*P
      DEPTH = (((-1.82E-11*P+2.279E-7)*P-2.2512E-3)*P+97.2659)*P
      DEPTH=DEPTH/GR
      RETURN
      END
C CPSW FCN *** OCT 3 1980 ****
      REAL FUNCTION CPSW(S,T,P0)
C ***************************
C SPECIFIC HEAT OF SEAWATER J/KG
C SALINITY PSU (IPSS-78), TEMPERATURE DEG. CELSIUS (IPTS-68),
C PRESSURE IN DECIBARS.
```

```
C REF: MILLERO ET AL,1973,JGR,78,4499-4507
C PRESSURE VARIATION FROM LEAST SQUARES POLYNOMIAL
C DEVELOPED BY FOFONOFF 1980.
C CHECK VALUE: CPSW = 3850.309 J/KG FOR S = 40 PSU,
C T = 40 DEG C, P0= 10000 DECIBARS
C   SCALE PRESSURE TO BARS
   P=P0/10.
C**************************
C SQRT SALINITY FOR FRACTIONAL TERMS
   SR = SQRT(ABS(S))
C SPECIFIC HEAT CP0 FOR P=0 (MILLERO ET AL 1973)
   A = (-1.3839E-3*T+0.107276)*T-7.6444
   B = (5.3539E-5*T-4.0772E-3)*T+0.17709
   C = (((2.093236E-5*T-2.654387E-3)*T+0.1412855)*T
  X    -3.720283)*T+4217.4
   CP0 = (B*SR + A)*S + C
C CP1 PRESSURE AND TEMPERATURE TERMS FOR S = 0
   A = (((1.7168E-8*T+2.0357E-6)*T-3.13885E-4)*T+1.45747E-2)*T
  X   -0.49592
   B = (((2.2956E-11*T-4.0027E-9)*T+2.87533E-7)*T-1.08645E-5)*T
  X   +2.4931E-4
   C = ((6.136E-13*T-6.5637E-11)*T+2.6380E-9)*T-5.422E-8
   CP1 = ((C*P+B)*P+A)*P
C CP2 PRESSURE AND TEMPERATURE TERMS FOR S > 0
   A = (((-2.9179E-10*T+2.5941E-8)*T+9.802E-7)*T-1.28315E-4)*T
  X   +4.9247E-3
   B = (3.122E-8*T-1.517E-6)*T-1.2331E-4
   A = (A+B*SR)*S
   B = ((1.8448E-11*T-2.3905E-9)*T+1.17054E-7)*T-2.9558E-6
   B = (B+9.971E-8*SR)*S
   C = (3.513E-13*T-1.7682E-11)*T+5.540E-10
   C = (C-1.4300E-12*T*SR)*S
   CP2 = ((C*P+B)*P+A)*P
C SPECIFIC HEAT RETURN
   CPSW = CP0 + CP1 + CP2
   RETURN
   END
C ATG FCN *** OCT 20 1980 ****
   REAL FUNCTION ATG(S,T,P0)
C ***************************
C ADIABATIC TEMPERATURE GRADIENT DEG C PER DECIBAR
C REF: BRYDEN,H.,1973,DEEP-SEA RES.,20,401-408
C UNITS:
```

```
C      PRESSURE       P0      DECIBARS
C      TEMPERATURE    T     DEG CELSIUS (IPTS-68)
C      SALINITY       S       PSU (IPSS-78)
C      ADIABATIC      ATG     DEG. C/DECIBAR
C CHECK: ATG=3.255976E-4 C/DBAR FOR S=40 PSU,T=40 DEG C,
P0=10000 DECIBAR
C   SCALE PRESSURE TO BARS
   P=P0/10.
C*************************
   DS = S - 35.0
   ATG = (((-2.1687E-13*T+1.8676E-11)*T-4.6206E-10)*P
  X+((2.7759E-10*T-1.1351E-8)*DS+((-5.4481E-12*T
  X+8.733E-10)*T-6.7795E-8)*T+1.8741E-6))*P
  X+(-4.2393E-7*T+1.8932E-5)*DS
  X+((6.6228E-9*T-6.836E-7)*T+8.5258E-5)*T+3.5803E-4
C    SCALE ATG TO PER DECIBAR
    ATG=0.1*ATG
C****************
    RETURN
    END
C THETA FCN ****** OCT 20 1980 ******
REAL FUNCTION THETA(S,T0,P0,PR)
C **********************************
C TO COMPUTE LOCAL POTENTIAL TEMPERATURE AT PR
C USING BRYDEN 1973 POLYNOMIAL FOR ADIABATIC LAPSE
C RATE AND RUNGE-KUTTA 4-TH ORDER INTEGRATION
C ALGORITHM.
C REF: BRYDEN,H.,1973,DEEP-SEA RES.,20,401-408
C FOFONOFF,N.,1977,DEEP-SEA RES.,24,489-491
C UNITS:
C      PRESSURE       P0     DECIBARS
C      TEMPERATURE    T0     DEG CELSIUS (IPTS-68)
C      SALINITY       S       PSU (IPSS-78)
C      REFERENCE PRS    PR      DECIBARS
C      POTENTIAL TMP.  THETA    DEG CELSIUS
C CHECKVALUE: THETA= 36.89072 C,S=40 PSU,T0=40 DEG C,
C P0=10000 DECIBARS,PR=0 DECIBARS
C
C    SET-UP INTERMEDIATE TEMPERATURE AND PRESSURE
      VARIABLES
   P=P0
   T=T0
C**************
   H = PR - P
   XK = H*ATG(S,T,P)
```

```
      T = T + 0.5*XK
      Q = XK
      P = P + 0.5*H
      XK = H*ATG(S,T,P)
      T = T + 0.29289322*(XK-Q)
      Q = 0.58578644*XK + 0.121320344*Q
      XK = H*ATG(S,T,P)
      T = T + 1.707106781*(XK-Q)
      Q = 3.414213562*XK - 4.121320344*Q
      P = P + 0.5*H
      XK = H*ATG(S,T,P)
      THETA = T + (XK-2.0*Q)/6.0
      RETURN
      END
C SVEL FCN **** OCT 4 1980 *****
      REAL FUNCTION SVEL(S,T,P0)
C ******************************
C SOUND SPEED SEAWATER CHEN & MILLERO 1977,JASA,62,
C 1129-1135 UNITS:
C     PRESSURE      P0     DECIBARS
C     TEMPERATURE   T      DEG CELSIUS (IPTS-68)
C     SALINITY      S      PSU (IPSS-78)
C     SOUND SPEED   SVEL   METERS/SECOND
C CHECKVALUE: 1731.995 M/S FOR P0=10000 DECIBARS,
T=40 DEG C, S=40 PSU
C
      EQUIVALENCE (A0,B0,C0),(A1,B1,C1),(A2,C2),(A3,C3)
C
C   SCALE PRESSURE TO BARS
      P=P0/10.
C**************************
      SR = SQRT(ABS(S))
C S**2 TERM
      D = 1.727E-3 - 7.9836E-6*P
C S**3/2 TERM
      B1 = 7.3637E-5 +1.7945E-7*T
      B0 = -1.922E-2 -4.42E-5*T
      B = B0 + B1*P
C S**1 TERM
      A3 = (-3.389E-13*T+6.649E-12)*T+1.100E-10
      A2 = ((7.988E-12*T-1.6002E-10)*T+9.1041E-9)*T-3.9064E-7
      A1 = (((-2.0122E-10*T+1.0507E-8)*T-6.4885E-8)*T-1.2580E-5)*T
     X    +9.4742E-5
```

```
   A0 = (((-3.21E-8*T+2.006E-6)*T+7.164E-5)*T-1.262E-2)*T
  X    +1.389
   A = ((A3*P+A2)*P+A1)*P+A0
C S**0 TERM
   C3 = (-2.3643E-12*T+3.8504E-10)*T-9.7729E-9
   C2 = (((1.0405E-12*T-2.5335E-10)*T+2.5974E-8)*T-1.7107E-6)*T
  X    +3.1260E-5
   C1 = (((-6.1185E-10*T+1.3621E-7)*T-8.1788E-6)*T+6.8982E-4)*T
  X    +0.153563
   C0 = ((((3.1464E-9*T-1.47800E-6)*T+3.3420E-4)*T-5.80852E-2)*T
  X    +5.03711)*T+1402.388
   C = ((C3*P+C2)*P+C1)*P+C0
C SOUND SPEED RETURN
   SVEL = C + (A+B*SR+D*S)*S
   RETURN
   END
C
C BRVAL ***** BRUNT-VAISALA FREQ *****
C USES 1980 EQUATION OF STATE
   FUNCTION BVFRQ(S,T,P,NOBS,PAV,E)
C ***********************************
C UNITS:
C     PRESSURE      P0     DECIBARS
C     TEMPERATURE     T     DEG CELSIUS (IPTS-68)
C     SALINITY        S       PSU (IPSS-78)
C     BOUYANCY FREQ    BVFRQ    CPH
C     N**2          E       RADIANS/SECOND
C CHECKVALUE: BVFRQ=14.57836 CPH E=6.4739928E-4 RAD/SEC.
C          S(1)=35.0, T(1)=5.0, P(1)=1000.0
C          S(2)=35.0, T(2)=4.0, P(2)=1002.0
C ********NOTE RESULT CENTERED AT PAV=1001.0 DBARS *******
C R MILLARD
C JULY 12 1982
C COMPUTES N IN CYCLES PER HOUR, & E=N**2 IN RAD/SEC**2
C AFTER FORMULATION OF BRECK OWEN'S
   REAL*4 P(1),T(1),S(1)
   E=0.0
   BVFRQ=0.0
   IF(NOBS.LT.2) RETURN
   CXX=0.0
   CX=0.0
```

```
   CXY=0.0
   CY=0.0
C COMPUTE LEAST SQUARES ESTIMATE OF SPECIFIC VOLUME
   ANAMOLY GRADIENT
   DO 20 K=1,NOBS
  20 CX =CX+P(K)
   PAV=CX/NOBS
   DO 35 K=1,NOBS
   DATA= SVAN(S(K),THETA(S(K),T(K),P(K),PAV),PAV,SIG)*1.0E-8
   CXY=CXY+DATA*(P(K)-PAV)
   CY =CY+DATA
   CXX=CXX+(P(K)-PAV)**2
  35 CONTINUE
   IF(CXX.EQ.0.0) RETURN
   A0=CXY/CXX
   V350P=(1./(SIG+1000.))-DATA
   VBAR=V350P+CY/NOBS
   DVDP=A0
C
   IF(VBAR.EQ.0.0) RETURN
   E = -.96168423E-2*DVDP/(VBAR)**2
   BVFRQ = 572.9578*SIGN(SQRT(ABS(E)),E)
   RETURN
   END
```

A.7 P-Vector Calculation

The subroutine *pvector* is used to compute the P-vector.

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

      subroutine pvector(stopog,deep,ktop,sims,sect1,sect2,f0,j)
      include 'pstate.h'
      common /maxval6/ veval,vmax,ii,jj
      real veval(nz),vmax(6,nz)
      integer ii(6,nz),jj(6,nz)
      integer sect1,sect2
```

```
c-----------------------------------------------------------------------
  real aa,aa1,aa2,aa3,dr,dq,drdq
  real fac
c-----------------------------------------------------------------------
  real dz,dz1,dz2
  real zero,one,two,small,sims
  real g,rho0
  integer i,j,i1,j1,k,kk,kk1,kk2,kbot
  integer mx1,mz1,kpv(nz),mkpv,ktop
  integer stopog(nx,ny)
  real uref,vref,deep(nz)
  real minlat
c-----------------------------------------------------------------------
  real f0,small_rhotz
  real a11,a12,a22,t11,t12,t22,ff1,ff2,wk,rxz,ryz
  integer jms,jmn
c – physical constants
  g=9.81
  rho0=1028.0
c – numerical constants
  zero=0.0
  one=1.0
  two=2.0
  small=1.e-7
  minlat=5.0
  jms=1
  jmn=0
  mz1=mz-1
  mx1=mx-1
  if(global.gt.0) mx1=mx

  small_rhotz=1.0e-20
c    f0=0.5*(abs(ff(1))+abs(ff(my)))
c
c – clear local array
c
     do i=1,mx
      do k=1,mz
        rhox(i,k)=0.0
        rhoy(i,k)=0.0
        rhotx(i,k)=0.0
        rhoty(i,k)=0.0
        rhotz(i,k)=0.0
        q(i,sect2,k)=0.0
```

```
        qx(i,k)=0.0
        qy(i,k)=0.0
        qz(i,k)=0.0
        px(i,k)=0.0
        py(i,k)=0.0
        pz(i,k)=0.0
        ug(i,k)=0.0
        vg(i,k)=0.0
        u(i,sect2,k)=0.0
        v(i,sect2,k)=0.0
        w(i,k)=0.0
            enddo
                enddo

c
c – calaulate potential velocity q= f drhot/dz:
c
      do i=1,mx
       kbot=istopog(i,j+1)
       if(kbot.ge.2) then
         q(i,sect2,1)=ff(j+1)*(rhot(i,sect2,1)-rhot(i,sect2,2))/
     &            (deep(1)-deep(2))/f0
         q(i,sect2,kbot)=ff(j+1)*(rhot(i,sect2,kbot-1)-
     &            rhot(i,sect2,kbot))/(deep(kbot-1)-deep(kbot))/f0
         do k=2,kbot-1
          dz1=deep(k-1)-deep(k)
          dz2=deep(k)-deep(k+1)
          dz= dz1+dz2
          q(i,sect2,k)=ff(j+1)/f0*((rhot(i,sect2,k-1)-rhot(i,sect2,k))


     &                          *dz2/(dz1*dz)+(rhot(i,sect2,k)-
     &                          rhot(i,sect2,k+1))*dz1/(dz2*dz))
                 enddo
               endif
             enddo
             if(j.eq.0) return


      c
      c –          rhotz=d rhot/dz and qz=dq/dz in the wet domain starting
     from ktop
      c            Not: rhotz and qz at the staged grid(B grid)
      c
```

```
      do i=1,mx1
        i1=i+1
        if(i1.gt.mx) i1=i1-mx
        if(rmask(i,j).gt.1) then
      kbot=rmask(i,j)
      rhotz(i,1)=0.25*(rhot(i,sect1,1)+rhot(i1,sect1,1)+
     *           rhot(i,sect2,1)+rhot(i1,sect2,1)-
     *           rhot(i,sect1,2)-rhot(i1,sect1,2)-
     *           rhot(i,sect2,2)-rhot(i1,sect2,2))/
     *           (deep(1)-deep(2))
      qz(i,1)=0.25*(q(i,sect1,1)+q(i1,sect1,1)+
     *         q(i,sect2,1)+q(i1,sect2,1)-q(i,sect1,2)-
     *         q(i1,sect1,2)-q(i,sect2,2)-
     *         q(i1,sect2,2))/(deep(1)-deep(2))
      rhotz(i,kbot)=(rhot(i,sect1,kbot-1)+
     *           rhot(i1,sect1,kbot-1)+
     *         rhot(i,sect2,kbot-1)+rhot(i1,sect2,kbot-1)-
     *         rhot(i,sect1,kbot)-rhot(i1,sect1,kbot)-
     *         rhot(i,sect2,kbot)-rhot(i1,sect2,kbot))/
     *         (deep(kbot-1)-deep(kbot))/4.0
      qz(i,kbot)=-1.0
      do k=2,kbot-1
        pcdz1=deep(k-1)-deep(k)
        dz2=deep(k)-deep(k+1)
        dz= dz1+dz2
        aa1=rhot(i,sect1,k-1)+rhot(i1,sect1,k-1)+
     *    rhot(i,sect2,k-1)+rhot(i1,sect2,k-1)
      aa2=rhot(i,sect1,k)+rhot(i1,sect1,k)+
     *    rhot(i,sect2,k)+rhot(i1,sect2,k)
      aa3=rhot(i,sect1,k+1)+rhot(i1,sect1,k+1)+
     *    rhot(i,sect2,k+1)+rhot(i1,sect2,k+1)
           rhotz(i,k)=0.25*((aa1-aa2)*dz2/(dz1*dz)+
     *    (aa2-aa3)*dz1/(dz2*dz))
           aa1=q(i,sect1,k-1)+q(i1,sect1,k-1)+q(i,sect2,k-1)
     *    +q(i1,sect2,k-1)
           aa2=q(i,sect1,k)+q(i1,sect1,k)+q(i,sect2,k)
     *    +q(i1,sect2,k)
           aa3=q(i,sect1,k+1)+q(i1,sect1,k+1)+q(i,sect2,k+1)
     *    +q(i1,sect2,k+1)
           qz(i,k)=0.25*((aa1-aa2)*dz2/(dz1*dz)+
     *    (aa2-aa3)*dz1/(dz2*dz))
           enddo
         endif
        enddo
```

```
c
c – scale the d/dz
c
      do i=1,mx1
        do k=1,mz
          rhotz(i,k)=rhotz(i,k)*fac_scale
          qz(i,k)=qz(i,k)*fac_scale
        enddo
      enddo
c
c – calculate rhotx, rhoty, rhotz, rhox and rhoy
c – rhox=d rho/dx; rhoy= d rho/dy; etc.
c
      do i=1,mx1
       i1=i+1
       if(i1.gt.mx) i1=i1-mx
       kbot=rmask(i,j)
       if(kbot.ge.1) then
          do k=1,kbot
            rhox(i,k)=(rho(i1,sect1,k)+rho(i1,sect2,k)-
     *          rho(i,sect1,k)-rho(i,sect2,k))/(dx(j)+dx(j+1))
          rhoy(i,k)=-(rho(i,sect2,k)+rho(i1,sect2,k)-
     *          rho(i,sect1,k)-rho(i1,sect1,k))/(2.0*dy)
          rhotx(i,k)=(rhot(i1,sect1,k)+rhot(i1,sect2,k)-
     *         rhot(i,sect1,k)-rhot(i,sect2,k))/(dx(j)+dx(j+1))
          rhoty(i,k)=-(rhot(i,sect2,k)+rhot(i1,sect2,k)-
     *          rhot(i,sect1,k)-rhot(i1,sect1,k))/(2.0*dy)
          qx(i,k)=(q(i1,sect1,k)+q(i1,sect2,k)-q(i,sect1,k)
*               -q(i,sect2,k))/(dx(j)+dx(j+1))
          qy(i,k)=-(q(i,sect2,k)+q(i1,sect2,k)-q(i,sect1,k)
*               -q(i1,sect1,k))/(2.0*dy)
        enddo
        qx(i,kbot)=(stopog(i1,j)+stopog(i1,j+1)-stopog(i,j)-
*               stopog(i,j+1))/(dx(j)+dx(j+1))
        qy(i,kbot)=-(stopog(i1,j+1)+stopog(i,j+1)-stopog(i1,j)-
*               stopog(i,j))/(2.0*dy)
c – compute geostrophic shear (trapezoidal rule)
          fac=g/((ff(j)+ff(j+1))*rho0)
          ug(i,kbot)=0.0
          vg(i,kbot)=0.0
          do k=kbot,2,-1
```

```
            ug(i,k-1)=ug(i,k)+fac*(rhoy(i,k)+rhoy(i,k-1))
     *                *(deep(k-1)-deep(k))
            vg(i,k-1)=vg(i,k)-fac*(rhox(i,k)+rhox(i,k-1))
     *                *(deep(k-1)-deep(k))
          enddo
        endif
      enddo
c
c – compute the p vector, pvec = (px, py, pz)
c
c
c set p-vector to zero first (for plotting purposes)
c
      do i=1,mx1
        mkpv=0
        do k=ktop,rmask(i,j)-1
          aa1=1.0d10*(rhoty(i,k)*qz(i,k)-rhotz(i,k)*qy(i,k))
          aa2=1.0d10*(rhotz(i,k)*qx(i,k)-rhotx(i,k)*qz(i,k))
          aa3=1.0d10*(rhotx(i,k)*qy(i,k)-rhoty(i,k)*qx(i,k))
          aa=sqrt(aa1**2+aa2**2+aa3**2)
          dr=sqrt(rhotx(i,k)**2+rhoty(i,k)**2+rhotz(i,k)**2)
          dq=sqrt(qx(i,k)**2+qy(i,k)**2+qz(i,k)**2)
          drdq=aa/(1.0d10*dr*dq)
          if(drdq.ge.sims) then
            aa3=aa3*fac_scale
c           aa1=aa1/fac_scale
c           aa2=aa2/fac_scale
            aa=sqrt(aa1**2+aa2**2+aa3**2)
          px(i,k)=aa1/aa
          py(i,k)=aa2/aa
          pz(i,k)=aa3/aa
          mkpv=mkpv+1
          kpv(mkpv)=k
        endif
      enddo
c
c – optimization the uref and vref
c

        if(mkpv.ge.3) then
          t11=0.0
          t12=0.0
          t22=0.0
          ff1=0.0
          ff2=0.0
```

```
      do kk=1,mkpv
        k=kpv(kk)
        if(abs(rhotz(i,k)).gt.small_rhotz) then
          kk1=max(1,k-1)
          kk2=min(mz,k+1)
          wk=((deep(kk1)-deep(kk2))*1.0e-2)**power
          rxz=rhotx(i,k)/rhotz(i,k)
     *                *fac_scale
          ryz=rhoty(i,k)/rhotz(i,k)
     *                *fac_scale
          aa=1.0+rxz**2+ryz**2
          a11=wk*py(i,k)**2*aa
          a12=-wk*px(i,k)*py(i,k)*aa
          a22=wk*px(i,k)**2*aa
          t11=t11+a11
          t12=t12+a12
          t22=t22+a22
          ff1=ff1-a11*ug(i,k)-a12*vg(i,k)
          ff2=ff2-a12*ug(i,k)-a22*vg(i,k)
        endif
      enddo
      aa=t11*t22-t12**2
      if(aa.ne.0.0) then
        uref=(ff1*t22-ff2*t12)/aa
      vref=(t11*ff2-t12*ff1)/aa
      invmask(i,j)=rmask(i,j)
      do k=1,rmask(i,j)
        u(i,sect2,k)=uref+ug(i,k)
        v(i,sect2,k)=vref+vg(i,k)
      enddo
        else
        invmask(i,j)=-1
      endif
      else
        invmask(i,j)=-1
      endif
        if(rmask(i,j).eq.0) invmask(i,j)=1
      enddo
c
c – re-scale back
c
```

```
c
c – scale here before inversion, then re-scale back at the end
c
      do k=1,mz
        do i=1,mx1
          rhotz(i,k)=rhotz(i,k)/fac_scale
          qz(i,k)=qz(i,k)/fac_scale
        enddo
      enddo

c
c – compute vertical velocity
c
      if(j.gt.1) then
      do i=1,mx1
        i1=i-1
        if(i1.lt.1 .and. global.gt.0) i1=i1+mx
        if(i1.gt.0) then
          kbot=min(istopog(i,j),max(rmask(i,j),rmask(i1,j),
     *               rmask(i,j-1),rmask(i1,j-1)))
          if(kbot.ge.2) then
            uref=0.0
            vref=0.0
            mkpv=0
            do k=i1,i,(i-i1)
      do j1=1,2
      if(u(k,j1,kbot).ne.0.0) then
        uref=uref+u(k,j1,kbot)
        vref=vref+v(k,j1,kbot)
        mkpv=mkpv+1
        endif
      enddo
      enddo
      if(mkpv.gt.0) then
        uref=uref/mkpv
        vref=vref/mkpv
        w(i,kbot)=(uref*(stopog(i+1,j)-stopog(i1,j))/dx(j)
     *           +vref*(stopog(i,j-1)-stopog(i,j+1))/dy)/2.0
        do k=kbot-1,1,-1
          uref=(u(i,sect2,k)+u(i,sect2,k+1)+u(i,sect1,k)+
     *           u(i,sect1,k+1)-u(i1,sect2,k)
     *           -u(i1,sect2,k+1)-u(i1,sect1,k)-
     *           u(i1,sect1,k+1))/(2.0*(dx(j)+dx(j+1)))
          vref=(v(i,sect1,k)+v(i,sect1,k+1)+v(i1,sect1,k)+
     *          v(i1,sect1,k+1)-v(i,sect2,k)-v(i,sect2,k+1)-
     *          v(i1,sect2,k)-v(i1,sect2,k+1))/(4.0*dy)
        w(i,k)=w(i,k+1)-(uref+vref)*(deep(k)-deep(k+1))
```

```
      enddo
     endif
    endif
   endif
  enddo
endif

do k=ktop,mz
  do i=1,mx1
    aa=sqrt(u(i,sect2,k)**2+v(i,sect2,k)**2)
    call maxn(6,vmax,aa,ii,jj,i,j,k)
    veval(k)=veval(k)+aa
  enddo
enddo

return
end

subroutine maxn(n,v,a,ii,jj,i,j,kk)
parameter(nz=50)
integer i,j,k,kk,n,i,l,ii(n,nz),jj(n,nz)
real a,v(n,nz)
if(a.ge.v(1,kk)) then
  do k=n,2,-1
    v(k,kk)=v(k-1,kk)
    ii(k,kk)=ii(k-1,kk)
    jj(k,kk)=jj(k-1,kk)
  enddo
  v(1,kk)=a
  ii(1,kk)=i
  jj(1,kk)=j
else
  do k=2,n
    if(a.ge.v(k,kk) .and. a.lt.v(k-1,kk)) then
      do l=n,k+1,-1
        v(l,kk)=v(l-1,kk)
        ii(l,kk)=ii(l-1,kk)
        jj(l,kk)=jj(l-1,kk)
      enddo
      v(k,kk)=a
      ii(k,kk)=i
      jj(k,kk)=j
    endif
  enddo
endif

return
end
```

A.8 Avoiding P-Vector Calculation

The subroutine *setmask* is used to determine the area where the P-vector calculation is not valid (necessary conditions not being satisfied).

```
------------------------------------------
******************************************
      subroutine setmask(mx,my,istopog,rmask,invmask,global)
      parameter(nx=360,ny=180)
      integer istopog(nx,ny),rmask(nx,ny),invmask(nx,ny)
      integer i,j,i1,i2,i3,j1,j2,j3,mx,my,mx1,my1
      mx1=mx-1
      if(global.eq.1) mx1=mx
      my1=my-1
      do j=1,my1
           do i=1,mx1
            rmask(i,j)=0
           invmask(i,j)=0
         enddo
      enddo
c
c – calculate rmask
c
      do i=1,mx-1
         do j=1,my1
           rmask(i,j)=min(istopog(i,j),istopog(i,j+1),istopog(i+1,j),
     &                  istopog(i+1,j+1))
         enddo
      enddo
      if(global.eq.1) then
        do j=1,my1
          rmask(mx,j)=min(istopog(1,j),istopog(1,j+1),
     &                  istopog(mx,j),istopog(mx,j+1))
        enddo
      endif
  c
  c – re-calaulate rmask to void
  c
       do i=1,mx1
        do j=1,my1
          if(global.eq.1) then
           i1=i-1
           i2=i-2
           i3=i-3
           if(i1.lt.1) i1=i1+mx
           if(i2.lt.1) i2=i2+mx
```

```
        if(i3.lt.1) i3=i3+mx
        j1=i+1
        j2=i+2
        j3=i+3
        if(j1.gt.mx) j1=j1-mx
        if(j2.gt.mx) j2=j2-mx
        if(j3.gt.mx) j3=j3-mx
       else
       i1=max(1,i-1)
       i2=max(1,i-2)
       i3=max(1,i-3)
       j1=min(mx1,i+1)
       j2=min(mx1,i+2)
       j3=min(mx1,i+3)
      endif
      kk1=max(min(rmask(i,j),rmask(i1,j),rmask(i2,j),rmask(i3,j)),
     &        min(rmask(i,j),rmask(j1,j),rmask(j2,j),rmask(j3,j)))
      i1=max(1,j-1)
      i2=max(1,j-2)
      i3=max(1,j-3)
      j1=min(my1,j+1)
      j2=min(my1,j+2)
      j3=min(my1,j+3)
      kk2=max(min(rmask(i,j),rmask(i,i1),rmask(i,i2),rmask(i,i3)),
     &        min(rmask(i,j),rmask(i,j1),rmask(i,j2),rmask(i,j3)))
      rmask(i,j)=min(kk1,kk2)
     enddo
    enddo

    return
    end
```

A.9 Data Output

The following subroutines (*matopen*, *matout*, *matotal*, *matclose*) are used for the data output.

```
**********************************************************
*
     subroutine matopen(iuvuni,iunpxy,iunrho,iunuvg,iunq)
     integer iuvuni,iunpxy,iunrho,iunuvg,iunq
     open(iuvuni,file='puv.dat')
     open(iunpxy,file='pxyz.dat')
     open(iunrho,file='prho.dat')
     open(iunuvg,file='puvg.dat')
     open(iunq,file='pqxyz.dat')
     return
     end
**********************************************************
```

```
      subroutine matotal(mx1,my1,mz,istopog,rmask,invmask,deep,
      &         grid_size,lon0,lat0,ktop,pref,global)
      parameter(nx=360,ny=180,nz=50)
      integer invmask(nx,ny),rmask(nx,ny),istopog(nx,ny)
      integer i,j,k,mx1,my1,mz,ktop,iunit
      real pref,deep(nz),grid_size,lon0,lat0
c – control
      iunit=10
      open(iunit,file='pctrl.dat',form='formatted')
      write(iunit,102) mx1,my1,mz,grid_size,lat0,
      $       lon0,ktop,pref,global
      close(iunit)

c – masks
      open(iunit,file='pmask.dat',form='formatted')
      do i=1,mx1
        do j=1,my1
          write(iunit,103)
      $         invmask(i,j),min(istopog(i,j),istopog(i,j+1),
      $         istopog(i+1,j),istopog(i+1,j+1)),rmask(i,j)
        enddo
      enddo
      close(iunit)

      open(iunit,file='pdeep.dat',form='formatted')
      do k=1,mz
        write(iunit,101) deep(k)
      enddo
      close(iunit)
101     format(1x,e18.7)
102     format(3i4,3(1x,e18.7),i4,1x,e16.7,2x,i3)
103     format(5i8)

      return

      end

**************************************************
      subroutine matout(iuvuni,iunpxy,iunrho,iunuvg,iunq,
      &                 temp,salt,sect,f0)
      include 'pstate.h'
      real temp(nx,2,nz),salt(nx,2,nz),s2day,f0
```

```
      data s2day/86400.0/
      integer iuvuni,iunpxy,iunrho,iunuvg,iunq
      integer i,i1,k,mx1,sect
      mx1=mx-1

      if(global) mx1=mx
c – primary fields
      do i=1,mx1
        do k=1,mz
          write(iuvuni,100) u(i,sect,k),v(i,sect,k),s2day*w(i,k)
        enddo
      enddo

      do i=1,mx1
        do k=1,mz
          write(iunpxy,100) px(i,k),py(i,k),pz(i,k)
        enddo
      enddo

      do i=1,mx1
        i1=i+1
        if(i1.gt.mx) i1=i1-mx
        do k=1,mz
          write(iunrho,100)
     &         .25*(temp(i,1,k)+temp(i,2,k)+temp(i1,1,k)+temp(i1,2,k)),
     &         .25*(salt(i,1,k)+salt(i,2,k)+salt(i1,1,k)+salt(i1,2,k)),
     &         .25*(rho(i,1,k)+rho(i,2,k)+rho(i1,1,k)+rho(i1,2,k)),
     &         .25*(rhot(i,1,k)+rhot(i,2,k)+rhot(i1,1,k)+rhot(i1,2,k))
        enddo
      enddo

      do i=1,mx1
        do k=1,mz
          write(iunuvg,100) ug(i,k),vg(i,k)
        enddo
      enddo

      do i=1,mx1
        do k=1,mz
          write(iunq,100) (q(i,1,k)+q(i,2,k)+q(i1,1,k)+q(i1,2,k))
     &                *f0/4.0, qx(i,k), qy(i,k), qz(i,k)
        enddo
      enddo
```

```
 100   format(4(1x,e18.7))
 101   format(1x,e18.7)
 102   format(3i4,3(1x,e18.7),i4,1x,e16.7)
 103   format(5i8)

       return
       end
```

```
      ********************************************************
      subroutine matotal(mx1,my1,mz,istopog,rmask,invmask,deep,
      &           grid_size,lon0,lat0,ktop,pref,global)
      parameter(nx=360,ny=180,nz=50)
      integer invmask(nx,ny),rmask(nx,ny),istopog(nx,ny)
      integer i,j,k,mx1,my1,mz,ktop,iunit
      real pref,deep(nz),grid_size,lon0,lat0
c – control
      iunit=10
      open(iunit,file='pctrl.dat',form='formatted')
      write(iunit,102) mx1,my1,mz,grid_size,lat0,
      $      lon0,ktop,pref,global
      close(iunit)

c – masks
      open(iunit,file='pmask.dat',form='formatted')
      do i=1,mx1
        do j=1,my1
          write(iunit,103)
      $        invmask(i,j),min(istopog(i,j),istopog(i,j+1),
      $        istopog(i+1,j),istopog(i+1,j+1)),rmask(i,j)
        enddo
      enddo
      close(iunit)

      open(iunit,file='pdeep.dat',form='formatted')
      do k=1,mz
        write(iunit,101) deep(k)
      enddo
      close(iunit)
101   format(1x,e18.7)
102   format(3i4,3(1x,e18.7),i4,1x,e16.7,2x,i3)
103   format(5i8)

      return
      end
```

```
**************************************************
*
      subroutine matclose(iuvuni,iunpxy,iunrho,iunuvg,iunq)
      integer iuvuni,iunpxy,iunrho,iunuvg,iunq
      close(iuvuni)
      close(iunpxy)
      close(iunrho)
      close(iunuvg)
      close(iunq)
      return
      end
```

B

P-Vector Module for Isopycnal-Coordinate

Similar to Appendix A, the P-Vector module for isopycnal-coordinate is presented in Appendix B. This module is also stored in the enclosed DVD-Rom including the makefile, source codes, plotting files (using Matlab), and a sample case. Rongfeng Li and Chenwu Fan helped in developing these codes. Here, the code with the NetCDF output is listed for illustration.

B.1 Main Program

```
c     This program is calculating absolute current on isopycnals
c     at this subdirector program is running from south to north
c
c     sigmapvnc.f
c
c     to compile:
c        f77 -o sigmapvnc sigmapvnc.f -L/usr/local/netcdf-3.4/lib -
lnetcdf
c     Note: you may need to correct the netcdf lib path. If there is no
c        Netcdf lib support in your system, ask your system
c        administrator to download the netcdf lib.
c



      include 'comblk.h'
      include 'netcdf.inc'

      real lon0, lat0, latmin, lonm0, latm0
      integer data_type, dim3d(3), dim2d(2),
     &    ist3(3),ict3(3),dimts3d(3), istts3(3), ictts3(3)
c        data_type 0-ASCII 1-binary
      real*8 facu, fact, ofstst, ofstr, factpv
      integer*2 i1d(im*(kl+jm)), i1s(im*kl), gb2
      integer*1 i11d(im*kl)
      character titl*80, author*20, created*9
```

```
      data facu, factpv/1.0d-4,1.0d-2/
      data fact, ofstst, ofstr/1.0d-3, 1.5d1, 30.0d0/
      data pi/3.1415926535/
      data radius/6.371e6/omega/7.292e-5/ g/9.806/
      data rho0/1025./

      data rlim/32767.0/
      data gb2 /-32767/

      data ist3,ict3/1,1,1,kl1,im1,1/
      data istts3,ictts3/1,1,1,kl,im,1/
      open(8,file='input.dat')
        read(8,*) lat0,lon0,y_gridsize,x_gridsize,data_type
        read(8,*) layers(1),drho, pref
        read(8,*) deep
        read(8,'(a20)') author
        read(8,'(a80)') titl
        read(8,*) kts,kpvect,kq
      close(8)

      do k=1,km1
        deepm(k)=(deep(k)+deep(k+1))/2.0
      enddo

      deg2rad=pi/180.
      small=1.e-6

      lonm0=lon0+x_gridsize/2.0
      latm0=lat0+y_gridsize/2.0

      latmin=5.
c ———— form depths spd (246) for interpolation ————
      spd(1)=deep(1)
      do kk=1,km-1
        dd=(deep(kk+1)-deep(kk))/nkp
        do k=nkp*(kk-1)+2,nkp*kk+1
          spd(k)=spd(k-1)+dd
        enddo
      enddo


c – calculating lat(j) lon(i),ff(j) Change them when using another
c       domain

      do j=1,jm
        lat(j)=lat0+y_gridsize*(j-1)
      enddo
```

```
      ddx=x_gridsize*deg2rad*radius
      dy=y_gridsize*deg2rad*radius

      do j=1,jm
        dx(j)=ddx*cos(lat(j)*deg2rad)
        ff(j)=2.*omega*sin(lat(j)*deg2rad)
        if(lat(j).lt.latmin .and. lat(j) .ge.0.0) then
         ff(j)=2.*omega*sin(latmin*deg2rad)
        endif
        if(lat(j).gt.-latmin .and. lat(j) .le.0.0) then
         ff(j)=-2.*omega*sin(latmin*deg2rad)
        endif
      enddo

c ———— for wnp pref=0.0 taking isopynals as follow ——
      do k=2,kl
        layers(k)=layers(1)+drho*(k-1)
        layerm(k-1)=0.5*(layers(k-1)+layers(k))
      enddo

      call date(created)

      IRET = NF_CREATE('pvout.nc',NF_CLOBBER,NCID)
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,NF_GLOBAL,
     &          'title',80,titl)
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,NF_GLOBAL,'author',29,
     &                  author//created)
      CALL ERRCHECK(IRET)
c
c     defind dimensions (lat, lon, lev)
c
      IRET = NF_DEF_DIM(NCID,'lat',jm,IDJDIM)
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_DIM(NCID,'lat_uv',jm1,IDJUVDIM)
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_DIM(NCID,'lon',im,IDIDIM)
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_DIM(NCID,'lon_uv',im1,IDIUVDIM)
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_DIM(NCID,'zlev',km,IDKDIM)
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_DIM(NCID,'sigma_level',kl,IDsigDIM)
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_DIM(NCID,'sigma_level_uv',kl1,IDsigmDIM)
      CALL ERRCHECK(IRET)
```

```
c     defined coordinate data (lat, lon, deep)
c

      IRET = NF_DEF_VAR(NCID,'lat',NF_float,1,IDJDIM,
     &           IDYCOORD)
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_VAR(NCID,'lat_uv',NF_float,1,IDJUVDIM,
     &           IDYUVCOORD)
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_VAR(NCID,'lon',NF_float,1,IDIDIM,
     &           IDXCOORD)
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_VAR(NCID,'lon_uv',NF_float,1,
     &           IDIUVDIM,IDXUVCOORD)
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_VAR(NCID,'depth',NF_float,1,
     &           IDKDIM,IDZCOORD)
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDZCOORD,
     &           'units',6,'meters')
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_VAR(NCID,'sigma_level',NF_float,1,
     &           IDsigDim,IDsig)
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDsig,'units',7,'kg/m**3')
      CALL ERRCHECK(IRET)
      IRET = NF_DEF_VAR(NCID,'sigma_level_uv',NF_float,1,
     &           IDsigmDim,IDsigm)
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDsigm,'units',7,'kg/m**3')
      CALL ERRCHECK(IRET)

      IRET = NF_PUT_ATT_TEXT(NCID,IDYCOORD,'long_name',
     &           30, 'Latitudinal Position for T,S,R')
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDYUVCOORD,
     &           'long_name',28, 'Latitudinal Position for u,v')
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDXCOORD,
     &           'long_name',31, 'Longitudinal Position for T,S,R')
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDXUVCOORD,
     &           'long_name',29, 'Longitudinal Position for u,v')
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDZCOORD,
     &           'long_name',27, 'Vertical Position for T,S,R')
      CALL ERRCHECK(IRET)
```

```
   dim3d(1)=IDsigmDIM
   dim3d(2)=IDIUVDIM
   dim3d(3)=IDJUVDIM

   dim2d(1)=IDIUVDIM
   dim2d(2)=IDJUVDIM

   dimts3d(1)=IDsigDim
   dimts3d(2)=IDIDIM
   dimts3d(3)=IDJDIM

   IRET = NF_DEF_VAR(NCID,'ktop',NF_SHORT,2,
&          dim2d,IDKTOP)
   CALL ERRCHECK(IRET)

   IRET = NF_PUT_ATT_TEXT(NCID,IDKTOP,'long_name',21,
&          'Top Sigma Level Index')
   CALL ERRCHECK(IRET)

   IRET = NF_DEF_VAR(NCID,'kbot',NF_SHORT,2,dim2d,
&          IDKBOT)
   CALL ERRCHECK(IRET)

   IRET = NF_PUT_ATT_TEXT(NCID,IDKBOT,'long_name',24,
&          'Bottom Sigma Level Index')
   CALL ERRCHECK(IRET)

  if(kts.gt.0) then
   IRET = NF_DEF_VAR(NCID,'temperature',NF_SHORT,3,
&          dimts3d,IDT)
   CALL ERRCHECK(IRET)
   IRET = NF_PUT_ATT_TEXT(NCID,IDT,'units',1,'C')
   CALL ERRCHECK(IRET)
   IRET = NF_PUT_ATT_DOUBLE(NCID,IDT,'scale_factor',
&          NF_double,1,fact)
   CALL ERRCHECK(IRET)
   IRET = NF_PUT_ATT_DOUBLE(NCID,IDT,'add_offset',
&          NF_double,1,ofstst)
   CALL ERRCHECK(IRET)
   IRET = NF_DEF_VAR(NCID,'salinity',NF_SHORT,3,
&          dimts3d,IDS)
   CALL ERRCHECK(IRET)
   IRET = NF_PUT_ATT_DOUBLE(NCID,IDS,'scale_factor',
&          NF_double,1,fact)
   CALL ERRCHECK(IRET)
   IRET = NF_PUT_ATT_DOUBLE(NCID,IDS,'add_offset',
&          NF_double,1,ofstst)
   CALL ERRCHECK(IRET)
   IRET = NF_PUT_ATT_TEXT(NCID,IDS,'units',3,'PSU')
   CALL ERRCHECK(IRET)
```

```
      IRET = NF_DEF_VAR(NCID,'sigma_depth',NF_float,3,
     &           dimts3d, IDsdep)
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDsdep,'units',1,'m')
      CALL ERRCHECK(IRET)
     endif

     if(kq.gt.0) then
      IRET = NF_DEF_VAR(NCID,'q',NF_float,3,dim3d,IDQ)
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDQ,'long_name',19,
     &                 'Potential Vorticity')
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDQ,'units',3,'1/s')
      CALL ERRCHECK(IRET)
     endif

      IRET = NF_DEF_VAR(NCID,'u',NF_SHORT,3,dim3d,IDU)
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDU,'long_name',14,
     &                 '3-D u-velosity')
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDU,'units',3,'m/s')
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_DOUBLE(NCID,IDU,'scale_factor',
     &                 NF_double,1,facu)
      CALL ERRCHECK(IRET)

      IRET = NF_DEF_VAR(NCID,'v',NF_SHORT,3,dim3d,IDV)
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDV,'long_name',14,
     &                 '3-D v-velosity')
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDV,'units',3,'m/s')
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_DOUBLE(NCID,IDV,'scale_factor',
     &                 NF_double,1,facu)
      CALL ERRCHECK(IRET)

      IRET = NF_DEF_VAR(NCID,'sigma_depth_uv',NF_float,3,
     &           dim3d, IDsmdep)
      CALL ERRCHECK(IRET)
      IRET = NF_PUT_ATT_TEXT(NCID,IDsmdep,'units',1,'m')
      CALL ERRCHECK(IRET)
```

```
      if(kpvect.gt.0) then
       IRET = NF_DEF_VAR(NCID,'pvector_x',NF_BYTE,3,
     &           dim3d,IDPX)
       CALL ERRCHECK(IRET)
       IRET = NF_PUT_ATT_DOUBLE(NCID,IDPX,'scale_factor',
     &           NF_double,1,factpv)
       CALL ERRCHECK(IRET)
       IRET = NF_DEF_VAR(NCID,'pvector_y',NF_BYTE,3,
     &           dim3d,IDPY)
       CALL ERRCHECK(IRET)
       IRET = NF_PUT_ATT_DOUBLE(NCID,IDPY,'scale_factor',
     &                  NF_double,1,factpv)
       CALL ERRCHECK(IRET)
      endif

      IRET = NF_ENDDEF(NCID)
      CALL ERRCHECK(IRET)
c
c     write coordinate data
c
      r1d(1)=lon0
      do i=2,im
       r1d(i)=r1d(i-1)+x_gridsize
      enddo
      IRET = NF_PUT_VAR_real(NCID,IDXCOORD,r1d)
      CALL ERRCHECK(IRET)

      r1d(1)=lonm0
      do i=2,im1
       r1d(i)=r1d(i-1)+x_gridsize
      enddo
      IRET = NF_PUT_VAR_real(NCID,IDXUVCOORD,r1d)
      CALL ERRCHECK(IRET)

      IRET = NF_PUT_VAR_real(NCID,IDYCOORD,lat)
      CALL ERRCHECK(IRET)
      do j=1,jm1
       r1d(j)=(lat(j)+lat(j+1))/2.0
      enddo
      IRET = NF_PUT_VAR_real(NCID,IDYUVCOORD,r1d)
      CALL ERRCHECK(IRET)

      IRET = NF_PUT_VAR_real(NCID,IDZCOORD,deep)
      CALL ERRCHECK(IRET)
```

```
      IRET = NF_PUT_VAR_real(NCID,IDsig,layers)
      CALL ERRCHECK(IRET)

      IRET = NF_PUT_VAR_real(NCID,IDsigm,layerm)
      CALL ERRCHECK(IRET)
c
      is1=2
      is2=1

      ifdt=18
      ifds=19

      if(data_type.eq.0) then
        open(ifdt,file='t.txt')
        open(ifds,file='s.txt')
      else
        open(ifdt,file='t.bin',
     &       form='unformatted',access='direct',recl=km*im)
        open(ifds,file='s.bin',
     &       form='unformatted',access='direct',recl=km*im)
      endif

      j=0
      j1=j+1
      call qinput(ifdt,ifds,j1,data_type)

      call qlyddz(drho,is2,j1)

      istts3(3)=j1
      if(kts.gt.0) then
        do i=1,im
          if(kb(i,j1).le.kt(i,j1)) then
            do k=1,kl
              i1d(kl*(i-1)+k)=gb2
              i1s(kl*(i-1)+k)=gb2
            enddo
          else
            do k=1,kt(i,j1)-1
              i1d(kl*(i-1)+k)=gb2
              i1s(kl*(i-1)+k)=gb2
            enddo
            k1=1
            k2=k1+1
            do k=kt(i,j1),kb(i,j1)
              do while(lyd(k,i,is2).gt.deep(k2))
                k1=k2
                k2=k1+1
              enddo
```

```
            h1=(deep(k2)-lyd(k,i,is2))/(deep(k2)-deep(k1))
            h2=1.0-h1
            i1d(kl*(i-1)+k)=(tp(k1,i)*h1+tp(k2,i)*h2-ofstst)/fact+0.5
            i1s(kl*(i-1)+k)=(sp(k1,i)*h1+sp(k2,i)*h2-ofstst)/fact+0.5
          enddo
          do k=kb(i,j1)+1,kl
            i1d(kl*(i-1)+k)=gb2
            i1s(kl*(i-1)+k)=gb2
          enddo
        endif
      enddo

      IRET = NF_PUT_VARA_int2(NCID,IDT,istts3,ictts3,i1d)
      CALL ERRCHECK(IRET)

      IRET = NF_PUT_VARA_int2(NCID,IDS,istts3,ictts3,i1s)
      CALL ERRCHECK(IRET)

      IRET = NF_PUT_VARA_real(NCID,IDsdep,istts3,ictts3,
     &                        lyd(1,1,is2))
      CALL ERRCHECK(IRET)

      endif

      do 1000 j=1,jm1
        j1=j+1
        iiss=is1
        is1=is2
        is2=iiss

        print *,'j=',j

        call qinput(ifdt,ifds,j+1,data_type)

        call qlyddz(drho,is2,j1)

        call fmask(is2,j1)

        call qcv(is1,is2,j)

        call caluv(drho,rho0,small,is1,is2,j)
c
c – output
c
        istts3(3)=j+1
        ist3(3)=j

        if(kts.gt.0) then
          do i=1,im
            if(kb(i,j1).le.kt(i,j1)) then
```

```
        do k=1,kl
          i1d(kl*(i-1)+k)=gb2
          i1s(kl*(i-1)+k)=gb2
        enddo
      else
        do k=1,kt(i,j1)-1
          i1d(kl*(i-1)+k)=gb2
          i1s(kl*(i-1)+k)=gb2
        enddo
        k1=1
        k2=k1+1
        do k=kt(i,j1),kb(i,j1)
          do while(lyd(k,i,is2).gt.deep(k2))
            k1=k2
            k2=k1+1
          enddo
          h1=(deep(k2)-lyd(k,i,is2))/(deep(k2)-deep(k1))
          h2=1.0-h1
          i1d(kl*(i-1)+k)=(tp(k1,i)*h1+tp(k2,i)*h2-ofstst)/fact+0.5
          i1s(kl*(i-1)+k)=(sp(k1,i)*h1+sp(k2,i)*h2-ofstst)/fact+0.5
        enddo
        do k=kb(i,j1)+1,kl
          i1d(kl*(i-1)+k)=gb2
          i1s(kl*(i-1)+k)=gb2
        enddo
      endif
    enddo
    IRET = NF_PUT_VARA_int2(NCID,IDT,istts3,ictts3,i1d)
    CALL ERRCHECK(IRET)

    IRET = NF_PUT_VARA_int2(NCID,IDS,istts3,ictts3,i1s)
    CALL ERRCHECK(IRET)

    IRET = NF_PUT_VARA_real(NCID,IDsdep,istts3,ictts3,
&             lyd(1,1,is2))
    CALL ERRCHECK(IRET)
  endif
    if(kq.gt.0) then
      do i=1,im1
        if(maskb(i,j).le.maskt(i,j)) then
          do k=1,kl1
            r1d(kl1*(i-1)+k)=0.0
          enddo
        else
          do k=1,maskt(i,j)-1
            r1d(kl1*(i-1)+k)=0.0
          enddo
```

```
      do k=maskt(i,j),maskb(i,j)
        r1d(kl1*(i-1)+k)=0.25*(q(k,i,is1)+q(k,i,is2)+
&                              q(k,i+1,is1)+q(k,i+1,is2))
      enddo
      do k=maskb(i,j)+1,kl1
        r1d(kl1*(i-1)+k)=0.0
      enddo
    endif
  enddo
  IRET = NF_PUT_VARA_real(NCID,IDQ,ist3,ict3,r1d)
  CALL ERRCHECK(IRET)
 endif

 do i=1,im1
  do k=1,kl1
    uuu=u(k,i)/facu+0.5
    uuu=max(-rlim,uuu)
    uuu=min(rlim,uuu)
    i1d(kl1*(i-1)+k)=uuu
  enddo
 enddo
 IRET = NF_PUT_VARA_int2(NCID,IDU,ist3,ict3,i1d)
 CALL ERRCHECK(IRET)

 do i=1,im1
  do k=1,kl1
    uuu=v(k,i)/facu+0.5
    uuu=max(-rlim,uuu)
    uuu=min(rlim,uuu)
    i1d(kl1*(i-1)+k)=uuu
  enddo
 enddo
 IRET = NF_PUT_VARA_int2(NCID,IDV,ist3,ict3,i1d)
 CALL ERRCHECK(IRET)

 if(kpvect.gt.0) then
  do i=1,im1
    do k=1,kl1
      i11d(kl1*(i-1)+k)=px(k,i)/factpv
    enddo
  enddo
  IRET = NF_PUT_VARA_int1(NCID,IDPX,ist3,ict3,i11d)
  do i=1,im1
    do k=1,kl1
      i11d(kl1*(i-1)+k)=py(k,i)/factpv
    enddo
  enddo
  IRET = NF_PUT_VARA_int1(NCID,IDPY,ist3,ict3,i11d)
 endif
```

```
      IRET = NF_PUT_VARA_real(NCID,IDsmdep,ist3,ict3,lydm)
      CALL ERRCHECK(IRET)

1000 continue

      close(ifdt)
      close(ifds)

      do i=1,im1
        do j=1,jm1
          i1d(im1*(j-1)+i)=maskt(i,j)
        enddo
      enddo
      IRET = NF_PUT_VAR_int2(NCID,IDKTOP,i1d)
      CALL ERRCHECK(IRET)

      do i=1,im1
        do j=1,jm1
          i1d(im1*(j-1)+i)=maskb(i,j)
        enddo
      enddo
      IRET = NF_PUT_VAR_int2(NCID,IDKBOT,i1d)
      CALL ERRCHECK(IRET)

      IRET = NF_CLOSE(NCID)

      stop
      end
```

B.2 Graphic Interface

```
C
      SUBROUTINE ERRCHECK(IRET)
C*****************************************************
C
C     *ERRCHECK*    ERROR HANDLER FOR GRAPHICAL
C     INTERFACE
C
C     AUTHOR - ROGER PROCTOR AND PATRICK LUYTEN
C
C     LAST UPDATE - 12 Jul 1999 @(COHERENS)netcdfint.f 8.4
C
C
C     DESCRIPTION - WRITE ERROR MESSAGE AND STOP
C     EXECUTION OF THE PROGRAM
```

```
C       IF AN ERROR OCCURS IN ONE OF THE netCDF
C       ROUTINES
C
C       REFERENCE -
C
C       CALLING PROGRAM - CDF2D, CDF3D
C
C       EXTERNALS - NF_STRERROR
C
C*************************************************
C
      INCLUDE 'netcdf.inc'

C
C*      ARGUMENTS
C
      INTEGER IRET

      IF (IRET.NE.NF_NOERR) THEN
        WRITE (0,*) NF_STRERROR(IRET)
        STOP
      ENDIF

      RETURN

      END
c — This program is for inputing data of T and S and then
c      interpolating T,S from 56 levels into 246 levels
c
c      qinput.f cf77 qinput.f intpo.f intpo.f

      subroutine qinput(ifdt,ifds,j,data_type)

      include 'comblk.h'

      real rhoz(kp)
      integer data_type

c ———— input tp(im,56) and sp(im,56) ————————-

      if(data_type.eq.0) then
        read(ifdt,*) tp
        read(ifds,*) sp
      else
        read(ifdt,rec=j) tp
        read(ifds,rec=j) sp
      endif
```

```
      do i=1,im
       itopo(i,j)=0
       do k=1,km
        if(tp(k,i).gt.-99.0 .and. sp(k,i).gt.-99.0) then
         itopo(i,j)=itopo(i,j)+1
        else
         goto 15
        endif
       enddo
15      continue
      enddo
```

B.3 Transformation of (T, S) Data from z- to Isopycnal-Coordinate

The subroutines *qinput.f*, *interpo.f*, and *cub.f* are used to input and to transform (T, S) data from z-levels (e.g., 33 levels in WOA atlas) to n_σ isopycnal levels (e.g., 236 isopycnal levels in Sect 6.6).

```
**************************************************
*
      subroutine qinput(ifdt,ifds,deep,tp,sp,spd,tpp,spp,is1,j)

      include 'comblk.h'

      real tp(mx,km,2),sp(mx,km,2)
      real tpp(mx,kp,2),spp(mx,kp,2)
      real deep(km),spd(kp)

      real rhoz(kp)
      dimension wk(mx,kp)
      dimension x(2,km),t(kp),a(km),b(km),s(kp)

c ———— input tp(mx,33) and sp(mx,33) ————————

*     read(ifdt,rec=my-j+1) ((tp(i,k,is1),k=1,km),i=1,mx)
*     read(ifds,rec=my-j+1) ((sp(i,k,is1),k=1,km),i=1,mx)
      read(ifdt,rec=my-j+1) ((tp(i,k,is1),i=1,mx),k=1,km)
      read(ifds,rec=my-j+1) ((sp(i,k,is1),i=1,mx),k=1,km)

c     print *,'reading T and S j= ',j

      if(j .eq.99 ) then
       print *,' tp(304,99,k)= '
       print 666,(tp(304,k,is1),k=1,km)
       print *,' sp(304,99,k)= '
       print 666,(sp(304,k,is1),k=1,km)
      endif
666     format(5f12.4)
```

```
      do 22 i=1,mx
       itopo(i,j)=0
       do k=1,km
        if(tp(i,k,is1).gt.-99.0 .and. sp(i,k,is1).gt.-99.0) then
          itopo(i,j)=itopo(i,j)+1
        endif
       enddo
22      continue

c ———————— intepolate tp(mx,33) into tpp(mx,236) ————————

      call intpo(tp,wk,deep,spd,x,t,a,b,s,is1,j)

      do 55 i=1,mx
      do 55 k=1,kp
55      tpp(i,k,is1)=wk(i,k)

c ———————— intepolate sp(mx,my,56) into spp(mx,my,246) ——

      call intpo(sp,wk,deep,spd,x,t,a,b,s,is1,j)

      do 56 i=1,mx
      do 56 k=1,kp
56      spp(i,k,is1)=wk(i,k)

c —— form index field itopp(i,j) according to tpp and spp ——
      do 23 i=1,mx
       itopp(i,j)=0
       do k=1,kp
        if(tpp(i,k,is1).gt.-99. .and. spp(i,k,is1).gt.-99.) then
          itopp(i,j)=itopp(i,j)+1
        endif
       enddo
23      continue

c ———————— calculating portential density rhot ————————————

      do 57 i=1,mx
      do 57 k=1,kp
         rho(i,k,is1)=0.0
         rhot(i,k,is1)=0.0
57      continue
      do 66 i=1,mx
       if(itopp(i,j) .eq. 0) go to 66
       do k=1,itopp(i,j)
          tempd=tpp(i,k,is1)
          saltd=spp(i,k,is1)
          pressure=spd(k)
```

```
        dum=svan(saltd,tempd,pressure,rho(i,k,is1))
        tempt=theta(saltd,tempd,pressure,pref)
        dumt=svan(saltd,tempt,pref,rhot(i,k,is1))
      enddo
66      continue

      if(j .eq.99 ) then
      print *,' rhot(304,99,k)= '
      print 666,(rhot(304,k,is1),k=1,kp)
      print *,' rhot(305,99,k)= '
      print 666,(rhot(305,k,is1),k=1,kp)
      endif

      return
      end
**********************************************
      subroutine intpo(ts,wk,deep,spd,x,t,a,b,s,is1,j)
      include 'comblk.h'

      real ts(mx,km,2)
      real wk(mx,kp)
      real deep(km),spd(kp)

      dimension x(2,km),t(kp),a(km),b(km),s(kp)

c ------------------------------------------------
      do 11 i=1,mx
      do 11 k=1,kp
11      wk(i,k)=-99.9999

c ---- intepolating ts(mx,km) to wk(mx,kp) ----------

      do 100 i=1,mx
        kkb=itopo(i,j)
        if(itopo(i,j).le.1) go to 100
        q1=ts(i,1,is1)
        q2=ts(i,2,is1)
        y11=(q2-q1)/(deep(2)-deep(1))
        q3=ts(i,kkb-1,is1)
        q4=ts(i,kkb,is1)
        yn1=(q4-q3)/(deep(kkb)-deep(kkb-1))

        dd=deep(kkb)
        if(dd.gt.0.0.and.dd.le.1000.) then
          m=ifix(dd/10.+1.e-10)+1
        else if(dd.gt.1000.0 .and. dd .le.2500.) then
           m=ifix((dd-1000.)/20.+1.e-10)+101
        else if(dd.gt.2500.0.and.dd.le.5500.) then
             m=ifix((dd-2500.)/50.+1.e-10)+176
        endif
```

```
      if(i.eq.304 .and. j.eq.99) then
        print *,' for B point i=304, j=99 '
        print *,' m= ',m,' kb= ',kkb,' deep(kkb)= ',deep(kkb)
      endif

      do k=1,kp
        t(k)=0.0
        s(k)=0.0
      enddo
      do kk=1,m
        t(kk)=spd(kk)
      enddo

      do k=1,km
        x(1,k)=deep(k)
        x(2,k)=ts(i,k,is1)
        a(k)=0.0
        b(k)=0.0
      enddo

      call cub(km,kkb,m,kp,x,t,a,b,s,y11,yn1)

      do kk=1,m
        wk(i,kk)=s(kk)
      enddo

100     continue

      return
      end

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

subroutine cub(n,ns,m,mb,x,t,a,b,s,y11,yn1)
      dimension x(2,n),a(n),b(n),t(mb),s(mb)

      a(1)=0.0
      b(1)=y11
c       n1=n-1
      n1=ns-1
      do 1 j=2,n1
        h1=x(1,j)-x(1,j-1)
        h=x(1,j+1)-x(1,j)
        af=h1/(h+h1)
        bt=3.*((1.-af)*(x(2,j)-x(2,j-1))/h1+af*(x(2,j+1)-x(2,j))/h)
        a(j)=-af/(2.+(1.-af)*a(j-1))
1       b(j)=(bt-(1.-af)*b(j-1))/(2.+(1.-af)*a(j-1))
c       a(n)=yn1
        a(ns)=yn1
2       a(n1)=a(n1)*a(n1+1)+b(n1)
        n1=n1-1
        if(n1.gt.0) go to 2
```

```
      do 5 j=1,m
        i=1
3       if(t(j).le.x(1,i+1)) go to 4
        i=i+1
        go to 3
4       h=x(1,i+1)-x(1,i)
        h1=(x(1,i+1)-t(j))/h
        h2=(t(j)-x(1,i))/h
5       s(j)=(3.-2.*h1)*h1**2*x(2,i)+(3.-2.*h2)*h2**2*x(2,i+1)+
     &       (1.-h1)*h1**2*h*a(i)-(1.-h2)*h2**2*h*a(i+1)

      return
      end
```

B.4 Calculation of Level Depth, Layer Thickness, and Potential Vorticity

The subroutine *qlyddz* is used to calculate the level depth (lyd), layer thickness (dz) and potential vorticity (q).

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

      subroutine qlyddz(drho,layers,spd,is1,j)

      include 'comblk.h'

      real layers(mz),spd(kp),rhoz(kp)

c ------------ Calculate the level depth ------------
      do 88 i=1,mx
      do 88 k=1,mz
88      lyd(i,k,is1)=9999.9

      do 99 k=1,kp
99      rhoz(k)=0.0
      do 11 i=1,mx
        mb=itopp(i,j)
        if(mb.le.1) goto 11
       do k=1,mb
        rhoz(k)=rhot(i,k,is1)
       enddo
       do k=1,mz
        rhof=layers(k)
        lyd(i,k,is1)=dpint(kp,mb,spd,rhoz,rhof,1)
       enddo
11    continue
```

```
c ———————— Calculate the layer thickness ————————
      do 12 i=1,mx
      do 12 k=1,mz-1
        dd=lyd(i,k+1,is1)-lyd(i,k,is1)
        if (lyd(i,k,is1).ge.lyd(i,k+1,is1).or.
     &                  lyd(i,k+1,is1).ge.9999.9) then
          dz(i,k,is1)=0.0
        else
          dz(i,k,is1)=dd
        endif
12    continue

c ———————— calculating q=drho/rhok*f/dz ————————
      do 63 i=1,mx
      do 63 k=1,mz-1
63      q(i,k,is1)=9999.9

      do 64 i=1,mx
      do 64 k=2,mz-1
         if (dz(i,k-1,is1).gt.0.0 .and. dz(i,k,is1).gt.0.0) then
           rhok=1000.0+(layers(k)+0.5*drho)
           fact=drho/rhok
           q(i,k,is1)=fact*ff(j)/dz(i,k,is1)
         endif
64     continue

      if(j.eq.100) then
        print *,' '
      print *, 'lyd(304,100,k)lyd(305,100,k)dz(304,100,k)dz(305,100,k)'
        print *,' '
          do k=1,mz-1
            dd1=lyd(304,k,is1)
            dd2=lyd(305,k,is1)
            print 56,k,dd1,dd2,dz(304,k,is1),dz(305,k,is1)
          enddo
      endif
      if(j.eq.99) then
        print *,' '
      print *,'lyd(304,99,k)lyd(305,99,k)dz(304,99,k)dz(305,99,k)'
        print *,' '
          do k=1,mz-1
            dd1=lyd(304,k,is1)
            dd2=lyd(305,k,is1)
            print 56,k,dd1,dd2,dz(304,k,is1),dz(305,k,is1)
          enddo
      endif
56     format(1x,i4,4f12.4)

      return
      end
```

B.5 Calculation of Absolute Velocity

The subroutine *caluvg* is used to calculate the abosulte velocity.

```
**************************************************
      subroutine caluvg(drho,rho0,small,is1,is2,j)

      include 'comblk.h'

      real hx(mx-1,mz-1),hy(mx-1,mz-1)
      real dhx(mz-1),dhy(mz-1)
c     real dumk(mz-1),dvmk(mz-1),hm(mz-1)
      real hm(mz-1)
      real pxm(mz-1),pym(mz-1)

c ————————— calculate hx and hy from South to North ——
      do 10 k=1,mz-1
      do 10 i=1,mx-1
         hx(i,k)=0.0
         hy(i,k)=0.0
         u(i,k)=0.0
         v(i,k)=0.0
         ug(i,k)=0.0
         vg(i,k)=0.0
10      continue

      do 21 i=1,mx-1
        ktop=maskt(i,j)
        kbot=maskb(i,j)
        if(ktop.gt.0 .and.ktop.lt.kbot) then
          do k=ktop,kbot
            q1=dz(i,k,is1)
            q2=dz(i+1,k,is1)
            q3=dz(i+1,k,is2)
            q4=dz(i,k,is2)
            if(q1 .gt.0.0 .and.q2 .gt.0.0 .and.
     &         q3 .gt.0.0 .and.q4 .gt.0.0) then
            hx(i,k)=(q3+q2-q4-q1)/(dx(j+1)+dx(j))
            hy(i,k)=(q3+q4-q2-q1)/(2.*dy)
            endif
          enddo
        endif
21    continue
```

```
c ———————— start to calculate current ————————
      do 1000 i=1,mx-1
        invmask(i,j)=0
       do k=1,mz-1
        u(i,k)=0.0
        v(i,k)=0.0
       enddo
1000   continue

      do 2000 i=1,mx-1
       ktop=maskt(i,j)+5
       kbot=maskb(i,j)-1

       if(ktop.gt.0 .and. ktop.lt.kbot) then
        fuv=0.5*(ff(j)+ff(j+1))
        if (fuv.eq.0.0) goto 2000
        fac=g*drho/(fuv*rho0)

c – calculate d(Mk-Mkbot)/dy/fac, d(Mk-Mkbot)/dx/fac
      do k=1,mz-1
       dhx(k)=0.0
       dhy(k)=0.0
       hm(k)=0.0
       pxm(k)=0.0
       pym(k)=0.0
      enddo

      do k=ktop,kbot
       dhx(k)=hx(i,k)
       dhy(k)=hy(i,k)
       pxm(k)=px(i,k)
       pym(k)=py(i,k)
       hm(k)=0.25*(dz(i,k,is1)+dz(i+1,k,is1)+
     &                  dz(i+1,k,is2)+dz(i,k,is2))
       ug(i,k)=-pmkm(mz,k,kbot,dhy)*fac
       vg(i,k)=pmkm(mz,k,kbot,dhx)*fac
      enddo

c —— optmxization the uref and vref ——————————
      t11=0.0
      t12=0.0
      t22=0.0
      ff1=0.0
      ff2=0.0
```

```
      do k=ktop,kbot
        wk=hm(k)**2
        a11=wk*pym(k)**2
        a12=-wk*pxm(k)*pym(k)
        a22=wk*pxm(k)**2
        t11=t11+a11
        t12=t12+a12
        t22=t22+a22
c       ff1=ff1-a11*dumk(k)-a12*dvmk(k)
c       ff2=ff2-a12*dumk(k)-a22*dvmk(k)
        ff1=ff1-a11*ug(i,k)-a12*vg(i,k)
        aff2=ff2-a12*ug(i,k)-a22*vg(i,k)
      enddo
        aa=t11*t22-t12**2
        if(abs(aa).ge.1.e-10) then
          uref=(ff1*t22-ff2*t12)/aa
          vref=(t11*ff2-t12*ff1)/aa
          invmask(i,j)=0
      do k=ktop,kbot
c       u(i,k)=uref+dumk(k)
c       v(i,k)=vref+dvmk(k)
        u(i,k)=uref+ug(i,k)
        v(i,k)=vref+vg(i,k)
      enddo
     else
       invmask(i,j)=-1
     endif
   endif
2000  continue

  if(j.eq.99) then
   print *,' '
   print *, 'u(304,99,k) v(304,99,k) '
   print *,' '
    do k=1,mz-1
     print 56,k,u(304,k),v(304,k)
    enddo
  endif
56  format(1x,i4,1x,2(1x,f9.6))

  return
  end
```

B.6 Functions

Several functions are difined for the computation.

```
**********************************************************
      function dpint(n,mb,dep,r,rhof,key)
       dimension dep(n),r(n)
       data eps/1.e-20/

       do i=1,mb-1
        if((r(i)-rhof)*(r(i+1)-rhof).le.0.0) goto 10
       enddo
       dpint=9999.9
       return

10      continue
       if(key.eq.1) then
        i2=i+1
        x1=(rhof-r(i2))/(r(i)-r(i2)+eps)
        dpint=dep(i)*x1+dep(i2)*(1.0-x1)
        return
       elseif(key.eq.2) then
        if(i.eq.1) then
         i1=1
         i2=2
         i3=3
        elseif(i.eq.mb-1) then
         i1=i-1
         i2=i
         i3=mb
        elseif((rhof-r(i))/(r(i+1)-r(i)+eps).le.0.5) then
         i1=i-1
         i2=i
         i3=i+1
        else
         i1=i
         i2=i+1
         i3=i+2
        endif
        dpint=dep(i1)*(rhof-r(i2))*(rhof-r(i3))/
     &              ((r(i1)-r(i2))*(r(i1)-r(i3))+eps)
     &     + dep(i2)*(rhof-r(i1))*(rhof-r(i3))/
     &              ((r(i2)-r(i1))*(r(i2)-r(i3))+eps)
     &     + dep(i3)*(rhof-r(i1))*(rhof-r(i2))/
     &              ((r(i3)-r(i1))*(r(i3)-r(i2))+eps)
        return
```

```
      else
       if(i.eq.1) then
        i1=1
        i2=2
        i3=3
        i4=4
       elseif(i.eq.mb-1) then
        i1=mb-3
        i2=mb-2
        i3=mb-1
        i4=mb
       else
        i1=i-1
        i2=i
        i3=i+1
        i4=i+2
       endif
       dpint=dep(i1)*(rhof-r(i2))*(rhof-r(i3))*(rhof-r(i4))/
     &         ((r(i1)-r(i2))*(r(i1)-r(i3))*(r(i1)-r(i4))+eps)
     &      +dep(i2)*(rhof-r(i1))*(rhof-r(i3))*(rhof-r(i4))/
     &         ((r(i2)-r(i1))*(r(i2)-r(i3))*(r(i2)-r(i4))+eps)
     &      +dep(i3)*(rhof-r(i1))*(rhof-r(i2))*(rhof-r(i4))/
     &         ((r(i3)-r(i1))*(r(i3)-r(i2))*(r(i3)-r(i4))+eps)
     &      +dep(i4)*(rhof-r(i1))*(rhof-r(i2))*(rhof-r(i3))/
     &         ((r(i4)-r(i1))*(r(i4)-r(i2))*(r(i4)-r(i3))+eps)
       return
      endif

      end
c ------------------------------------------------------------
      function pmkm(kl,kk,km,dh)
      real dh(kl-1)

      sumh=0.0
      do k=1,kl-1
       sumh=sumh+dh(k)
      enddo

      sumrok=0.0
      do j=1,kl-1-kk
       sumi=0.0
       do i=1,j
        sumi=sumi+dh(kl-i)
       enddo
       sumrok=sumrok+(sumh-sumi)
      enddo
```

```
      sumrom=0.0
       do j=1,kl-1-km
        sumi=0.0
        do i=1,j
          sumi=sumi+dh(kl-i)
        enddo
        sumrom=sumrom+(sumh-sumi)
      enddo

      pmkm=(sumrok-sumrom)
      end
```

B.7 Avoiding P-Vector Calculation

The subroutine *fmask* is used to determine the area where the P-vector calculation is not valid (necessary conditions not being satisfied).

```
**************************************************
*
      subroutine fmask(is1,j,key)

      include 'comblk.h'

      do 11 i=1,mx
         kt(i,j)=0
11       kb(i,j)=0
      do 12 i=1,mx-1
         maskt(i,j)=0
12       maskb(i,j)=0

      do 22 i=1,mx

        if(dz(i,1,is1).gt.0.1e-20) then
          kt(i,j)=1
        else
          do k=2,mz-1
            if(dz(i,k-1,is1).le.0.0.and.dz(i,k,is1).gt.0.1e-20) then
              kt(i,j)=k
              goto 22
            endif
          enddo
        endif
22    continue
```

```
      do 23 i=1,mx
         kb(i,j)=kt(i,j)
        do k=kt(i,j)+1,mz-1
         if(dz(i,k,is1).gt.0.0) then
           kb(i,j)=kb(i,j)+1
         endif
      enddo
23     continue

      if(key.eq.0) return

      do 25 i=1,mx-1
        msmax=max(kt(i,j),kt(i+1,j),kt(i+1,j+1),kt(i,j+1))
        msmin=min(kb(i,j),kb(i+1,j),kb(i+1,j+1),kb(i,j+1))
        if(msmax.ge.msmin) then
          maskt(i,j)=0
          maskb(i,j)=0
          maskc(i,j)=0
        else
          maskt(i,j)=msmax
          maskb(i,j)=msmin
          maskc(i,j)=8
        endif
25    continue

      if (j.eq.99 ) then
        print *,' kt(304,99) kt(305,99) kt(305,100) kt(304,100)'
        print 55, kt(304,99),kt(305,99),kt(305,100),kt(304,100)
        print *,' '
        print *,' maskt(304,99)= ',maskt(304,99)
        print *,' '
        print *,' kb(304,99) kb(305,99) kb(305,100) kb(304,100)'
        print 55, kb(304,99),kb(305,99),kb(305,100),kb(304,100)
        print *,' '
        print *,' maskb(304,99)= ',maskb(304,99)
        print *,' '
      endif
55     format (1x,i5,5x,i5,5x,i5,5x,i5)

      return
      end
```

C

Thermohaline Parametric Model

The codes for calculating the autocorrelation function and decorrelation scale from observational (T, S) profiles were originally written by Steven D. Haeger in 1994, modified by Charles Fralick in 1995 and by Qianqian Wang in 1998.

C.1 Makefile

```
*********************************************************
FFLAGS = -C     # check array bounds (default f77 compiling.)

GMODEL.OBJ = gmodel.o linr.o rms.o gfit.o grad3a.o grad3b.o dep1.o \
          g3at.o grad1.o dep2.o dep3t.o grad2.o dep3.o bump.o inout4.o\
          dep4.o dep4t.o grad4.o dep5.o dpall2.o
gmodel: $(GMODEL.OBJ)
          f77 -o $@ -n     $(GMODEL.OBJ) -L/usr/local/disspla11/lib \
```

C.2 Gradient Calculated from (T, S) Profiles

The program, *gradstat.f*, is use to calculate the vertical gradient from the (T, S) profile data, and to plot the gradient versus depth.

```
C ************************************************
C *                  PROGRAM GRADSTAT                *
C ************************************************
```

```
C INPUT FILE: 3 (MASTER FILE - UNFORMATTED)
C
C *** DEFINITION OF TEMP AND DEPTH VARIABLES ***
C
C  T: READ FROM MASTER FILE. PASSED TO LINR TO BE
C  INTERPOLATED.
C  T2: INTERPOLATED TEMP PASSED BACK FROM LINR AND
C  PASSED TO TOP.
C  GRAD: GRADIENT COMPUTED FROM T2
C  D: READ FROM MASTER FILE AND PASS TO LINR.
C  D2: DEPTH PASSED BACK FROM LINR.
C  D3: DEPTHS FOR GRADIENT PLOT (2 LESS THAN D2)
C
      CHARACTER IDENT*10,PARM*1,HEADER*60
      DIMENSION IFLAG(8),T(2500),D(2500)
      DIMENSION GRAD(201),D3(201)
      DIMENSION T2(201),D2(201)
      IU=3
      IEND=0
      ICNT=0
      ICNT1=0
      IERR0 = 0
       IERR1=0
       IERR2=0
       IERR3=0
       IERR4=0
      N=0
      IDAT=0
      IFIRST=0
C
C  M= NO OF SETS N= NO OF PTS EACH SET
C  X ARRAY CONTAINS COMPUTED MODEL COEFFICIENTS-
C  SEE COMMENTS IN TOP
C  FOR DESCRIPTION
C
C
       WRITE(6,*) ('WHAT IS MAX DEPTH OF GRAD MODEL? (M)')
       READ(5,*) DMAX
       WRITE(6,*) ('WHAT IS MIN DEPTH TO ACCEPT PROFILE? (M)')
       READ(5,*) DMIN
       WRITE(6,*) ('ENTER STARTING PROFILE')
       READ(5,*) IFIRST
       WRITE(6,*) ('HOW MANY PROFILES?')
       READ(5,*) NUMPRO
```

```
C
C
C  READ HEADER RECORD FROM MASTER FILE
C
     READ(3,ERR=9500) PARM,HEADER
     WRITE(6,600) PARM,HEADER
600 FORMAT(/,1X,'INPUT FILE DATA TYPE: ',A1,/, 1X,'HEADER:
',A60,/)
C
     WRITE(4,620) PARM,DMIN,DMAX
620 FORMAT(1X,A1,3X,F6.0,3X,F6.0)
C
C  LOOP THROUGH UNWANTED PROFILES
C
     IF(IFIRST.NE.1) THEN
     DO 100 I=1,IFIRST-1
     READ(3,END=9000,ERR=9500)
     NPROF,(IFLAG(J),J=1,8),XLAT,XLON,
    *JPROF,ICLAS,IPAT,IMASS,IPROV,
*WDEP1,WDEP2,IYEAR,IMON,IDAY,XHOUR,IDENT,ISOURC,NC
*YC1,NCYC2,
    *EXTRA,IEXTRA,(D(J),T(J),J=1,NCYC1+NCYC2)
     ICNT = ICNT+1
100 CONTINUE
   END IF
C
C READ DESIRED PROFILES FROM MASTER FILE
C
   DO 12 I=1,NUMPRO
   READ(3,END=9001,ERR=9500) NPROF,(IFLAG(J),J=1,8),XLAT,XLON,
   *JPROF,ICLAS,IPAT,IMASS,IPROV,
   *WDEP1,WDEP2,IYEAR,IMON,IDAY,XHOUR,IDENT,ISOURC,NCYC1,
   *NCYC2,
   *EXTRA,IEXTRA,(D(J),T(J),J=1,NCYC1+NCYC2)
   NCYC=NCYC1+NCYC2
   ICNT1 = ICNT1+1
C
C PROFILE HAS BEEN READ - CHECK FLAG(1) FOR UNWANTED
C PROFILE
C
   IF(IFLAG(1).NE.0) THEN
   IERR0 = IERR0+1
   GO TO 12
   END IF
```

```
C
C  CHECK TO SEE IF PROFILE EXTENDS TO DEPTH OF DMIN
C
      IF(D(NCYC).LT.DMIN) THEN
      IERR1 = IERR1+1
      GO TO 12
      END IF
      IKEEP = IKEEP+1
C
C  INTERPOLATE PROFILE TO D(NCYC) OR DMAX, WHICHEVER
C  WHICHEVER IS GREATER WITH LINR
C
     DELX = DMIN/50.
     IF(DELX.LT.2.) DELX = 2.
     BOT = DMAX
     IF(D(NCYC).LT.DMAX) BOT=D(NCYC)
     WRITE(6,*) ('DELX,BOT,D(NCYC) = '),DELX,BOT,D(NCYC)
     CALL LINR(DELX,NCYC,0.,BOT,ICT,D,T,D2,T2)
     WRITE(6,*) ('ICT = '),ICT
C
C  CALCULATE GRADIENT
C
     GMAX = 0.
     GMIN = 999.
     DO 20 J=1,ICT-1
     GRAD(J) = (T2(J+1)-T2(J)) / DELX
     D3(J) = D2(J) + (DELX/2.)
     IF(GRAD(J).GT.GMAX) GMAX = GRAD(J)
     IF(GRAD(J).LT.GMIN) GMIN = GRAD(J)
20   CONTINUE
     WRITE(6,605) GMIN,GMAX
605  FORMAT(1X,',GMIN,GMAX = ',2F8.4)
C
C
C WRITE FILE TO PLOT GRADIENT
C
     XMIN = -.1
     XMAX = .1
     DO 21 L=1,10
     IF(GMIN.LT.XMIN) XMIN = XMIN - .1
     IF(GMAX.GT.XMAX) XMAX = XMAX + .1
21 CONTINUE
     WRITE(11,33) GMIN,GMAX,XMIN,XMAX,ICNT,DMIN,DMAX
```

```
C
      GO TO 9002
C
9000 WRITE(6,650) ICNT
 650 FORMAT(1X,'BEGINNING PROFILE NOT FOUND',/,
     *1X,'EOF ENCOUNTERED AFTER PROFILE',I5,'. END
     * PROGRAM.')
      GO TO 1000
C
9001 IEND = 1
9002 LAST = IFIRST+ICNT1-1
      WRITE(6,651) ICNT1,IFIRST,LAST
651  FORMAT(1X,I5,' PROFILES READ FROM MASTER FILE',/,
     *1X,'FIRST PROFILE:',I5,5X,'LAST PROFILE:',I5)
      GO TO 1000
C
9500 ITOT = ICNT+ICNT1
      WRITE(6,652) ITOT
652 FORMAT(1X,'READ ERROR AFTER RECORD NUMBER
     *(PROFILE)',I5,/,
     *1X,'*CHECK MASTER FILE* PROGRAM TERMINATED.')
C
1000 CONTINUE
      END
```

C.3 Main Program

The software, gmodel.f, is used to calculate the thermohaline parameters from observational (T, S) profiles for nonpolar region (see Sect. 2.4). User may use different numbers of (depth, gradient) parameters (called *coefficient*s in the code).

```
C ***************************************************
C *                                                 *
C *                  PROGRAM GMODEL                 *
C *                                                 *
C ***************************************************
```

```
C
C
C  VERSION FOR YELLOW SEA CALCULATION (Section 2.4)
C
C  THIS PROGRAM READ PROFILES FROM THE MASTER FILE
C  AND COMPUTES
C  THE GRADIENT VS DEPTH.
C
C  INPUT FILE: 3 (MASTER FILE - UNFORMATTED)
C
C  *** DEFINITION OF TEMP AND DEPTH VARIABLES ***
C
C   T: READ FROM MASTER FILE. PASSED TO LINR TO BE
C   INTERPOLATED.
C   T2: INTERPOLATED TEMP PASSED BACK FROM LINR AND
C   PASSED TO TOP.
C   TM: MODELED TEMPS COMPUTED FROM MODELED
C   GRADIENTS
C   GRAD: GRADIENT COMPUTED FROM T2
C   XG: MODELED GRADIENT PASSED BACK FROM GFIT
C   D: READ FROM MASTER FILE. PASSED TO LINR.
C   D2: DEPTH PASSED BACK FROM LINR.
C   D3: DEPTHS FOR GRADIENT PLOT (ONE LESS THAN D2)
C
      CHARACTER IDENT*10,PARM*1,HEADER*60,IOPT*1
      CHARACTER HD*60
      DIMENSION IFLAG(8),T(2500),D(2500)
      DIMENSION GRAD(400),D3(400),XG(400)
      DIMENSION T2(401),D2(401),TM(401)
      DIMENSION CD(7),CG(7),COEF(11),X2(12)
      IU=3
      IEND=0
      ICNT=0
      ICNT1=0
      IERR0 = 0
       IERR1=0
       IERR2=0
       IERR3=0
       IERR4=0
      N=0
      IDAT=0
      IFIRST=0
C
      WRITE(6,604)
```

```
 604 FORMAT(//,1X,' — PROGRAM GMODEL —',/,
    *1X,'RUN BATHTAG FIRST IF DMIN WILL BE LESS THAN
     DMAX',/)
C
      CALL INOUT4
99    FORMAT (A25)
      OPEN (2,FILE='fguess.dat',FORM='FORMATTED',STATUS=
      'OLD')
      WRITE(6,*) ('WHAT IS MAX DEPTH OF GRAD MODEL? (M)')
      READ(5,*) DMAX
      WRITE(6,*) ('WHAT IS MIN DEPTH TO ACCEPT PROFILE?
      (M)')
      READ(5,*) DMIN
      WRITE(6,*) ('ENTER STARTING PROFILE')
      READ(5,*) IFIRST
      WRITE(6,*) ('HOW MANY PROFILES?')
      READ(5,*) NUMPRO
C
      WRITE(6,*) ('DO YOU WANT TO WRITE OUT COEFS?
      (Y OR N)')
      READ(5,500) IOPT
500   FORMAT(A1)
C*********************************************************
C READ HEADER RECORD FROM MASTER FILE
C*********************************************************
      READ(3,ERR=9500) PARM,HEADER
      WRITE(6,600) PARM,HEADER
600   FORMAT(/,1X,'INPUT FILE DATA TYPE: ',A1,/,
      *1X,'HEADER: ',A60,/)
      HD=('REJECTED PROFILES FROM GMODEL')
      WRITE(9) PARM,HD
      WRITE(8) PARM,HEADER
C
      WRITE(6,621) DMAX,DMIN
621   FORMAT(/,1X,'GRADIENT MODEL EXTENDS TO ',F6.0,' M',/,
      *1X,'PROFILES AT LEAST ',F4.0,' M WILL BE ACCEPTED',/)
C*********************************************************
C COMPUTE DELZ AND WRITE HEADER TO OUTPUT FILE
C*********************************************************
```

```
      DELZ = DMAX/400.
      IF(DELZ.LT.0.5) DELZ = 0.5
C
      IF(IOPT.EQ.'Y') THEN
      WRITE(4,609) DELZ,DMIN,DMAX
      WRITE(7,609) DELZ,DMIN,DMAX
609   FORMAT(1X,3F8.2)
      END IF
C*********************************************************
C  LOOP THROUGH UNWANTED PROFILES
C*********************************************************
       IF(IFIRST.NE.1) THEN
       DO 100 I=1,IFIRST-1
       READ(3,END=9000,ERR=9500)NPROF,(IFLAG(J),J=1,8),
       XLAT, XLON,
      *JPROF,ICLAS,IPAT,IMASS,IPROV,WDEP1,WDEP2,
       IYEAR,IMON,
      *IDAY,XHOUR,IDENT,ISOURC,NCYC1,NCYC2,
      *EXTRA,ICRUZ,(D(J),T(J),J=1,NCYC1+NCYC2)
       ICNT = ICNT+1
100    CONTINUE
       END IF
C*****************************************************************
C  READ DESIRED PROFILES FROM MASTER FILE
C*****************************************************************
     DO 12 I=1,NUMPRO
     READ(3,END=9001,ERR=9500) NPROF,(IFLAG(J),J=1,8),XLAT,
     XLON,
    *JPROF,ICLAS,IPAT,IMASS,IPROV,
    *WDEP1,WDEP2,IYEAR,IMON,IDAY,XHOUR,IDENT,ISOURC,
     NCYC1,
    *NCYC2,EXTRA,ICRUZ,(D(J),T(J),J=1,NCYC1+NCYC2)
     NCYC=NCYC1+NCYC2
     ICNT1 = ICNT1+1
     WRITE(6,*) ('PROFILE '),I
C*************************************************************
C  PROFILE HAS BEEN READ - CHECK FLAG(1) FOR UNWANTED
C  PROFILE
C*************************************************************
```

```
      IF(NPROF.EQ.42.OR.NPROF.EQ.29.OR.NPROF.EQ.315.
     *OR.NPROF.EQ.1234) THEN
       IERR0 = IERR0+1
       GO TO 12
      END IF
C*****************************************************************
C  CHECK TO SEE IF PROFILE EXTENDS TO DEPTH OF DMIN
C*****************************************************************
     IF(D(NCYC).LT.DMIN) THEN
      IERR1 = IERR1+1
      GO TO 12
     END IF
     IKEEP = IKEEP+1
C*****************************************************************
C  INTERPOLATE PROFILE TO D(NCYC) OR DMAX, WHICHEVER
C  WHICHEVER IS GREATEST.
C*****************************************************************
     BOT = DMAX
      IF(D(NCYC).LT.DMAX) BOT=D(NCYC)
      CALL LINR(DELZ,NCYC,0.,BOT,ICT,D,T,D2,T2)
C*****************************************************************
C  CALCULATE GRADIENT
C*****************************************************************
        GMAX = -999.
        GMIN = 999.
        DO 20 L=1,ICT-1
        GRAD(L) = (T2(L+1)-T2(L)) / DELZ
        D3(L) = D2(L) + (DELZ/2.)
        IF(GRAD(L).GT.GMAX) GMAX = GRAD(L)
        IF(GRAD( L).LT.GMIN) GMIN = GRAD(L)
  20   CONTINUE
C       WRITE(6,605) GMIN,GMAX
  605   FORMAT(//,1X,',GMIN,GMAX = ',2F8.4)
C*****************************************************************
C  CALL GRADFIT (GFIT) TO COMPUTE MODELED GRADIENT
C*****************************************************************
       ICT2 = ICT-1
       CALL GFIT(DELZ,ICT2,D3,GRAD,XG,D2,T2,CD,CG)
C*****************************************************************
C  COMPUTE MODELED TEMPERATURE FROM MODELED
    GRADIENT
C*****************************************************************
```

```
      TM(1) = T2(1)
      DO 30 L=2,ICT
 30   TM(L) = XG(L-1) * (D2(L)-D2(L-1)) + TM(L-1)
C*************************************************************
C  COMPUT FINAL RMS ERROR IN TEMPERATURE SPACE
C*************************************************************
   CALL RMS(TM,T2,ICT,R)
C*************************************************************
C  FILL COEFFICIENT ARRAY (ORIGINAL COEFS: DEPTHS AND
C  GRADIENTS)
C*************************************************************
C
      COEF(1) = T2(1)
      COEF(2) = CD(2)
     COEF(3) = CD(3)
     COEF(4) = CD(4)
     COEF(5) = CD(5)
     COEF(6) = CD(6)
     COEF(7) = CG(1)
     COEF(8) = CG(3)
     COEF(9) = CG(5)
     COEF(10) = CG(6)
     COEF(11) = CG(7)
C*************************************************************
C  IF DESRIRED, WRITE COEFFICIENTS TO UNIT 4
C*************************************************************
      IF(IOPT.EQ.'N') GO TO 24
      IF(R.GT.0.13) THEN
      GO TO 24
      END IF
     WRITE(4,610)NPROF,XLAT,XLON,WDEP2,(COEF(K),K=1,11),
     *NCYC1,IMASS
610  FORMAT(I5,2(F8.3,1X),F6.0,1X,F5.2,1X,5(F8.2,1X),5F8.4,I5,I4)
      WRITE(28,615) XLAT,XLON,COEF(1),COEF(2),COEF(3)
615  FORMAT(2(f8.3,2x),f5.2,2x,f8.2,2x,f8.2)
 24  CONTINUE
C
C*************************************************************
C  COMPUTE TEMPS AT DEPTHS OF COARSE GRADIENTS:
   THESE WILL
C  BE THE ACTUAL COEFFICIENTS FOR INTERPOLATION
C*************************************************************
```

```
      X2(1) = T2(1)
      CALL LINR(CD(2),ICT,CD(2),CD(2),ICT4,D2,TM,DOUT,TOUT)
      X2(2) = TOUT
      X2(8) = DOUT
      CALL LINR(CD(3),ICT,CD(3),CD(3),ICT4,D2,TM,DOUT,TOUT)
      X2(3) = TOUT
      X2(9) = DOUT
      CALL LINR(CD(4),ICT,CD(4),CD(4),ICT4,D2,TM,DOUT,TOUT)
      X2(4) = TOUT
      X2(10) = DOUT
      CALL LINR(CD(5),ICT,CD(5),CD(5),ICT4,D2,TM,DOUT,TOUT)
      X2(5) = TOUT
      X2(11) = DOUT
      CALL LINR(CD(6),ICT,CD(6),CD(6),ICT4,D2,TM,DOUT,TOUT)
      X2(6) = TOUT
      X2(12) = DOUT
      X2(7) = TM(ICT)
C ********************************************************
C     IF DESIRED, WRITE INTERPOLATED COEFS TO UNIT 7 AND
C     MASTER FILE PROFILE TO UNIT 8 (TO USE FOR STD
      DEPTH INTERP).
C     PROFILES NOT PASSING RMS TEST ARE WRITTEN TO
      MASTER FILE C 9.
C ********************************************************
      IF(IOPT.EQ.'N') GO TO 25
      IF(R.GT.0.13) THEN
      IRMS = IRMS+1
      WRITE(9) NPROF,(IFLAG(J),J=1,8),XLAT,XLON,
     *  JPROF,ICLAS,IPAT,IMASS,IPROV,
     *  WDEP1,WDEP2,IYEAR,IMON,IDAY,XHOUR,IDENT,ISOURC,
     *  NCYC1,NCYC2,
     *  EXTRA,ICRUZ,(D(J),T(J),J=1,NCYC1+NCYC2)
      GO TO 25
      END IF
C
      WRITE(7,611) NPROF,XLAT,XLON,WDEP2,(X2(K),K=1,12)
  611 FORMAT(I5,2(F8.3,1X),F6.0,7F8.3,5F8.2)
C
      WRITE(8) NPROF,(IFLAG(J),J=1,8),XLAT,XLON,
     * JPROF,ICLAS,IPAT,IMASS,IPROV, WDEP1,WDEP2,IYEAR,
      IMON,
     * IDAY,XHOUR,IDENT,ISOURC,NCYC1,NCYC2,
     * EXTRA,ICRUZ,(D(J),T(J),J=1,NCYC1+NCYC2)
```

```
 25   CONTINUE
C
 12   CONTINUE
      GO TO 9002
C
9000  WRITE(6,650) ICNT
650   FORMAT(1X,'BEGINNING PROFILE NOT FOUND',/,
     *1X,'EOF ENCOUNTERED AFTER PROFILE',I5,'.
      END PROGRAM.')
      GO TO 1000
C
9001  IEND = 1
9002  LAST = IFIRST+ICNT1-1
      WRITE(6,651) ICNT1,IFIRST,LAST
651   FORMAT(1X,I5,' PROFILES READ FROM MASTER FILE',/,
     *1X,'FIRST PROFILE:',I5,5X,'LAST PROFILE:',I5)
      GO TO 1000
C
9500  ITOT = ICNT+ICNT1
      WRITE(6,652) ITOT
652   FORMAT(1X,'READ ERROR AFTER RECORD NUMBER
     *(PROFILE)',I5,/,
     *1X,'*** CHECK MASTER FILE *** PROGRAM TERMINATED.')
C
 1000 CONTINUE
C
      WRITE(6,653) IERR1,IKEEP
653   FORMAT(/,1X,I5,' PROFILES NOT DEEP ENOUGH',/,
     *1X,I5,' PROFILES KEPT FOR PROCESSING')
C
      WRITE(6,654) IRMS
654   FORMAT(/,1X,I5,' PROFILE REJECTED FOR RMS GT 0.13 -
      SEE UNIT
     *9')
      CALL DONEPL
      END
```

C.4 Subroutines

C.4.1 Interpolation

The subroutine *LINR* is used for linear interpolation to fill the gaps in the input data.

```
**************************************************************
**
      SUBROUTINE LINR(DELX,N,XBGN,XEND,ICT,X,Y,AX,AY)
C     DELX=DESIRED INTERPOLATION INTERVAL, X AND Y
      ARE INPUT
C     WITH X=INDEP.
C     VARIABLE, AX AND AY ARE OUTPUT, N=LENGTH OF X,
      XBGN AND
C     XEND=DESIRED
C     BEGINNING AND ENDING VALUES OF AX,ICT=LENGTH OF AX
      DIMENSION X(*),Y(*),AX(*),AY(*)
      NN=N-1
      ICT=((XEND-XBGN)/DELX)+1.0001
      DO 1 J=1,ICT
      A=J-1
    1 AX(J)=A*DELX+XBGN
      KK=1
      DO 2 J=1,NN
      JJ=J+1
      SLOPE=(Y(JJ)-Y(J))/(X(JJ)-X(J))
      DO 3 K=KK,ICT
      I=K
      IF(AX(K).GT.X(JJ).AND.AX(K).LE.X(N)) GO TO 2
    3 AY(K)=SLOPE*(AX(K)-X(J))+Y(J)
      GO TO 4
    2 KK=I
    4 RETURN
      END
```

C.4.2 Iteration

As described in Sect. 2.4.3, the subroutine *BUMP* is used to perform an increment change in depth data; the soubroutine *RMS* is used to compute the root mean square error; and the subroutine *DEPALL* is used to cnduct the iteration.

```
*********************************************************
***
      SUBROUTINE BUMP(CD,LEVEL,DINC,IB,ISIGN,IGO)
C
C ******************************************
C *                                        *
C *       SUBROUTINE BUMP                  *
C *                                        *
C ******************************************
C
C
```

```
C    *** PARAMETERS PASSED TO BUMP
C
C    CD: DEPTH ARRAY (7) FOR COARSE DEPTHS (GRADIENT
      SPACE)
C    LEVEL: DEPTH BEING ADJUSTED IN CALLING PROGRAM
      (2-6)
C    DINC: DEPTH INTERVAL (METERS) FOR ADJUSTMENTS
C    IB: FLAG TO INDICATE WHAT TYPE OF BUMP DESIRED –
C      IB = 0: DONT BUMP ANY DEPTH
C      IB = 1: BUMP ONLY DEPTHS ABOVE (IF ADJ UPWARD)
C      IB = 2: BUMP ONLY DEPTHS BELOW (IF ADJ DOWNWARD)
C      IB = 3: BUMP ANY DEPTH (DEPENDING IF GOING UP OR
       DOWN)
C   ISIGN: FLAG TO INDICATE DIRCTION OF DEPTH ADJUSTMENT
C        (1 = ADDING DEPTHS, -1 = SUBTRACTING DEPTHS)
C
C   *** PARAMETERS PASSED BACK TO CALLING PROGRAM
C
C    CD: DEPTHS DEFINED ABOVE (BUT NOW USUALLY
      DIFFERENT)
C    IGO: FLAG TO TELL WHERE TO GO IN CALLING PROGRAM
C        (0 = CONTINUE, 1 = GO TO END OF CALLING SUBROUTINE)
C
C
     DIMENSION CD(7)
C
     IGO = 0
     L = LEVEL
     F1 = CD(1)
     F7 = CD(7)
C
     IF(ISIGN.EQ.1) GO TO 10
     IF(ISIGN.EQ.-1) GO TO 20
C
C ******************************************************
C CASE FOR ADDING DEPTHS IN CALLING SUBROUTINE
C ******************************************************
C
C DONT BUMP
C
```

```
10 CONTINUE
   IF(IB.EQ.0.OR.IB.EQ.1) THEN
   IF(CD(L).GE.CD(L+1)) THEN
   CD(L) = CD(L) - DINC
   IGO = 1
   END IF
   RETURN
   END IF
C
C  BUMP DEPTHS BELOW
C
     IF(IB.EQ.2.OR.IB.EQ.3) THEN
     LL = L
     DO 15 K=1,7-LL
     IF(CD(L).GE.CD(L+1)) THEN
      CD(L+1) = CD(L+1) + DINC
      L = L+1
     END IF
15   CONTINUE
C
C    IF BOTTOM DEPTH WAS BUMPED, MOVE ALL NECESSARY DEPTHS
C    UP
C
     IF(CD(7).GT.F7) THEN
      L = 7
      DO 17 K=1,7-LL
      CD(L) = CD(L) - DINC
        L = L-1
17      CONTINUE
        IGO = 1
        END IF
        RETURN
        END IF
C
C ****************************************************************
C CASE FOR SUBTRACTING DEPTHS IN CALLING SUBROUTINE
C ****************************************************************
C
```

```
C    DONT BUMP
C
    20 CONTINUE
       IF(IB.EQ.0.OR.IB.EQ.2) THEN
       IF(CD(L).LE.CD(L-1)) THEN
       CD(L) = CD(L) + DINC
       IGO = 1
       END IF
       RETURN
       END IF
C
C    BUMP DEPTHS ABOVE
C
       IF(IB.EQ.1.OR.IB.EQ.3) THEN
       LL = L
       DO 25 K=1,LL-1
       IF(CD(L).LE.CD(L-1)) THEN
       CD(L-1) = CD(L-1) - DINC
       pcL = L-1
       END IF
    25 CONTINUE
C
C    IF TOP DEPTH WAS BUMPED, MOVE ALL NECESSARY
     DEPTHS
C    BACK DOWN
C
  26 IF(CD(1).LT.F1) THEN
     L = 1
     DO 27 K=1,LL
     CD(L) = CD(L) + DINC
     L = L+1
27   CONTINUE
     IGO = 1
     GO TO 26
     END IF
     RETURN
     END IF
C
     END
  ************************************************
     SUBROUTINE RMS(XG,GRAD,ICT2,R)
     DIMENSION XG(*),GRAD(*)
     R = 0
     DO 10 J=1,ICT2
10   R = R + (XG(J)-GRAD(J))**2.
     RT = XG(J)-GRAD(J)
     R = (R/ICT2)**0.5
     RETURN
     END
```

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

   SUBROUTINE
   *DEPALL(DELX,SUR,BOT,ICT2,CD,CG,D3,GRAD,R,TOL,NI)
C
C ***********************************************************
C SUBROUTINE DEPALL
C MAKE INITIAL ADJUSTMENT OF D1,D2,D3,D4 (CD(2) - CD(5))
C ALSO ADJUST CD(6) AFTER ABOVE DEPTHS ARE ADJUSTED
C ***********************************************************
C
C
      DIMENSION D3(400),GRAD(400),CD(*),CG(*),XG(400)
      DIMENSION RR(400)
C
       IKEEP = 0
C      WRITE(6,606) (CD(J),J=1,7)
 606 FORMAT(1X,'INITIAL CDS: ',7F6.1)
C
C  CHECK FIRST TO SEE WHETHER TO ADD OR SUBTRACT
    DEPTHS
C
       ICNT = 0
       RMIN = 999.
       DINC = DELX
       R1 = R
C
C  COMPUTE DIFFERENCE BETWEEN CD(2) AND CD(1) AND
C  SUBTRACT
C  THIS FROM CD(2) THROUGH CD(5) FOR STARTING DEPTHS
C
       FIRST = CD(2)
       DIFF = CD(2) - CD(1)
       DO 5 K=2,5
    5 CD(K) = CD(K) - DIFF + DINC
C
C  FILL MODELED GRADIENT ARRAY WITH LINR USING NEW
    DEPTHS
C
       DO 80 M=1,ICT2
       CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
       CALL RMS(XG,GRAD,ICT2,R)
       ICNT = ICNT+1
C
       RR(ICNT) = R
       IF(RR(M).LE.RMIN) THEN
       IKEEP = ICNT
       RMIN = RR(M)
       END IF
```

```
C
      DO 6 K=2,5
    6 CD(K) = CD(K) + DINC
      IF(CD(5).GE.CD(6)) GO TO 85
   80 CONTINUE
C
C
   85 CONTINUE
      NEWCD2 = (IKEEP-1)*DINC
C
C ADJUST CD(2) THROUGH CD(5) TO OPTIMUM DEPTHS
C
      DIFF = CD(2) - NEWCD2
      DO 15 K=2,5
   15 CD(K) = CD(K) - DIFF + DINC
C
C COMPUTE INITIAL DEPTH FOR CD(6): 1/4 OF THE
C  DISTANCE BETWEEN
C CD(5) AND CD(7).
C
     DIFF2 = CD(6) - CD(5)
     CD(6) = CD(5) + 0.25*DIFF2
     CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
      CALL RMS(XG,GRAD,ICT2,R)
C
C     WRITE(6,604) (CD(J),J=1,7)
  604 FORMAT(1X,'NEW CDS: ',7F6.1)
      ADJ = FIRST - CD(2)
C     WRITE(6,605) ICNT,ADJ,R
  605 FORMAT(1X,' DEPALL ITNS:',I3,4X,'ADJ: ',F6.0,3X,
     *'RMS = ',F7.4)
      RETURN
      END
```

C.4.3 Mixed Layer Depth

The subroutine *DEP1* is used to determine the mixed layer depth.

```
   ************************************************************
      SUBROUTINE DEP1(DELX,SUR,BOT,ICT2,CD,CG,D3,
     *GRAD,R,TOL,NI,IB,IDUM)
C
C ************************************************************
C
C     SUBROUTINE DEP1
C     ADJUST D1 (CD(2)) - DEPTH OF MIXED LAYER
C
```

```
C     ************************************************
C
        DIMENSION D3(400),GRAD(400),CD(*),CG(*),XG(400)
C
C       CHECK FIRST TO SEE WHETHER TO ADD OR
        SUBTRACT
C       DEPTHS
C
        ICNT = 0
        FIRST = CD(2)
        DINC = DELX
        R1 = R
        CD(2) = CD(2) + DINC
        CALL BUMP(CD,2,DINC,IB,1,IGO)
        IF(IGO.EQ.1) GO TO 199
C
C       FILL MODELED GRADIENT ARRAY WITH LINR USING
C       NEW DEPTHS
C
        CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
        CALL RMS(XG,GRAD,ICT2,R)
        ICNT = ICNT+1
C
        IF(ABS(R-R1).LT.TOL) GO TO 199
c
c       IF(R.LT.R1) GO TO 100    @ GOING RIGHT WAY
c       IF(R.GT.R1) THEN    @ GOING WRONG WAY
c
        IF(R.LT.R1) GO TO 100
        IF(R.GT.R1) THEN
c
        CD(2) = CD(2) - DINC
        R = R1
        GO TO 150
        END IF
C
C       ADJUST D1 BY ADDING DEPTHS
C
  100   IF = 0
  102   IF(ICNT.GT.NI) GO TO 199
        R1 = R
        CD(2) = CD(2) + DINC
        CALL BUMP(CD,2,DINC,IB,1,IGO)
        IF(IGO.EQ.1) GO TO 199
C
        CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
        CALL RMS(XG,GRAD,ICT2,R)
        ICNT = ICNT+1
```

```
C
      IF(ABS(R-R1).LT.TOL) GO TO 199
      IF(R.LT.R1) GO TO 102
      IF(R.GT.R1.AND.IF.NE.4) THEN
      IF = IF+1
      CD(2) = CD(2) - DINC
      DINC = DINC/2.
      R = R1
      GO TO 102
      END IF
C
      GO TO 199
C
C     ADJUST D1 BY SUBSTRACTING DEPTHS
C
 150 IF = 0
 152 IF(ICNT.GT.NI) GO TO 199
      R1 = R
      CD(2) = CD(2) - DINC
      CALL BUMP(CD,2,DINC,IB,-1,IGO)
      IF(IGO.EQ.1) GO TO 199
C
      CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
      CALL RMS(XG,GRAD,ICT2,R)
      ICNT = ICNT+1
C
      IF(ABS(R-R1).LT.TOL) GO TO 199
      IF(R.LT.R1) GO TO 152
      IF(R.GT.R1.AND.IF.NE.4) THEN
      IF = IF+1
      CD(2) = CD(2) + DINC
      DINC = DINC/2.
      R = R1
      GO TO 152
      END IF
C
      GO TO 199
C
 199 CONTINUE
C
      ADJ = FIRST - CD(2)
C     WRITE(6,605) ICNT,ADJ,R
 605 FORMAT(1X,'D1 ITERATIONS: ',I3,4X,'ADJ: ',F6.0,3X,
     *'RMS = ',F7.4)
C
C
      RETURN
      END
```

C.4.4 Depth at the Top of Thermocline/Halocline

The subroutine DEP2 is used to determinine the depth at the top of thermocline (or halocline).

```
*******************************************************
      SUBROUTINE DEP2(DELX,SUR,BOT,ICT2,CD,CG,D3,GRAD,R,
      TOL,NI,*IB,IF)
C
C *******************************************************
C SUBROUTINE DEP2                                       *
C ADJUST D2 (CD(3)) - DEPTH OF TOP OF THERMOCLINE       *
C                                                       *
C *******************************************************
C
    DIMENSION D3(400),GRAD(400),CD(*),CG(*),XG(400)
C
C   CHECK FIRST TO SEE WHETHER TO ADD OR
    SUBTRACT DEPTHS
C
    ICNT = 0
    FIRST = CD(3)
    DINC = DELX
    R1 = R
    CD(3) = CD(3) + DINC
    CALL BUMP(CD,3,DINC,IB,1,IGO)
    IF(IGO.EQ.1) GO TO 199
C
C FILL MODELED GRADIENT ARRAY WITH LINR USING
  NEW DEPTHS
C
    CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
    CALL RMS(XG,GRAD,ICT2,R)
    ICNT = ICNT+1
C
    IF(ABS(R-R1).LT.TOL) GO TO 199
c
c   IF(R.LT.R1) GO TO 100      @ GOING RIGHT WAY
c   IF(R.GT.R1) THEN      @ GOING WRONG WAY
    IF(R.LT.R1) GO TO 100
    IF(R.GT.R1) THEN
c
    CD(3) = CD(3) - DINC
    R = R1
    GO TO 150
    END IF
```

```
C
C    ADJUST D2 BY ADDING DEPTHS
C
 100 IF = 0
 102 IF(ICNT.GT.NI) GO TO 199
     R1 = R
     CD(3) = CD(3) + DINC
     CALL BUMP(CD,3,DINC,IB,1,IGO)
     IF(IGO.EQ.1) GO TO 199
C
     CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
     CALL RMS(XG,GRAD,ICT2,R)
     ICNT = ICNT+1
C
     IF(ABS(R-R1).LT.TOL) GO TO 199
     IF(R.LT.R1) GO TO 102
     IF(R.GT.R1.AND.IF.NE.4) THEN
      IF = IF+1
      CD(3) = CD(3) - DINC
      DINC = DINC/2.
      R = R1
      GO TO 102
     END IF
C
     GO TO 199
C
C ADJUST D2 BY SUBSTRACTING DEPTHS
C
 150 IF = 0
 152 IF(ICNT.GT.NI) GO TO 199
      R1 = R
      CD(3) = CD(3) - DINC
      CALL BUMP(CD,3,DINC,IB,-1,IGO)
      IF(IGO.EQ.1) GO TO 199
C
      CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
      CALL RMS(XG,GRAD,ICT2,R)
      ICNT = ICNT+1
C
     IF(ABS(R-R1).LT.TOL) GO TO 199
     IF(R.LT.R1) GO TO 152
     IF(R.GT.R1.AND.IF.NE.4) THEN
```

```
      IF = IF+1
      CD(3) = CD(3) + DINC
      DINC = DINC/2.
      R = R1
      GO TO 152
      END IF
C
      GO TO 199
C
  199 CONTINUE
C
      ADJ = FIRST - CD(3)
C     WRITE(6,605) ICNT,ADJ,R
  605 FORMAT(1X,'D2 ITERATIONS: ',I3,4X,'ADJ: ',F6.0,3X,
     *'RMS = ',F7.4)
C
    RETURN
    END
```

C.4.5 Depth at the Bottom of Thermocline/Halocline

The subroutine DEP3 is used to determinine the depth at the bottom of thermocline (or halocline).

```
*******************************************************
    SUBROUTINE DEP3(DELX,SUR,BOT,ICT2,CD,CG,D3,GRAD,R,
    TOL,NI,*IB,IF)
C
C ************************************************************
C SUBROUTINE DEP3                                            *
C ADJUST D3 (CD(4)) - DEPTH OF BOTTOM OF THERMOCLINE         *
C OR HALOCLINE                                               *
C ************************************************************
C
    DIMENSION D3(400),GRAD(400),CD(*),CG(*),XG(400)
C
C   CHECK FIRST TO SEE WHETHER TO ADD OR SUBTRACT
    DEPTHS
C
    ICNT = 0
    FIRST = CD(4)
    DINC = DELX
```

```
      R1 = R
      CD(4) = CD(4) + DINC
      CALL BUMP(CD,4,DINC,IB,1,IGO)
      IF(IGO.EQ.1) GO TO 199
C
C     FILL MODELED GRADIENT ARRAY WITH LINR USING
      NEW DEPTHS
C
      CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
      CALL RMS(XG,GRAD,ICT2,R)
      ICNT = ICNT+1
C
      IF(ABS(R-R1).LT.TOL) GO TO 199
c
c       IF(R.LT.R1) GO TO 100    @ GOING RIGHT WAY
c       IF(R.GT.R1) THEN    @ GOING WRONG WAY
        IF(R.LT.R1) GO TO 100
        IF(R.GT.R1) THEN
c
        CD(4) = CD(4) - DINC
        R = R1
        GO TO 150
        END IF
C
C     ADJUST D3 BY ADDING DEPTHS
C
 100   IF = 0
 102   IF(ICNT.GT.NI) GO TO 199
       R1 = R
      CD(4) = CD(4) + DINC
      CALL BUMP(CD,4,DINC,IB,1,IGO)
      IF(IGO.EQ.1) GO TO 199
C
      CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
      CALL RMS(XG,GRAD,ICT2,R)
      ICNT = ICNT+1
C
      IF(ABS(R-R1).LT.TOL) GO TO 199
      IF(R.LT.R1) GO TO 102
      IF(R.GT.R1.AND.IF.NE.10) THEN
       IF = IF+1
       CD(4) = CD(4) - DINC
       DINC = DINC/2.
       R = R1
       GO TO 102
     END IF
```

```
C
    GO TO 199
C
C ADJUST D3 BY SUBSTRACTING DEPTHS
C
 150 IF = 0
 152 IF(ICNT.GT.NI) GO TO 199
      R1 = R
     CD(4) = CD(4) - DINC
     CALL BUMP(CD,4,DINC,IB,-1,IGO)
     IF(IGO.EQ.1) GO TO 199
C
    CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
    CALL RMS(XG,GRAD,ICT2,R)
    ICNT = ICNT+1
C
    IF(ABS(R-R1).LT.TOL) GO TO 199
    IF(R.LT.R1) GO TO 152
    IF(R.GT.R1.AND.IF.NE.10) THEN
     IF = IF+1
     CD(4) = CD(4) + DINC
     DINC = DINC/2.
     R = R1
     GO TO 152
     END IF
C
    GO TO 199
C
 199 CONTINUE
C
     ADJ = FIRST - CD(4)
     WRITE(6,605) ICNT,ADJ,R
605  FORMAT(1X,'D3 INTERATIONS: ',I3,4X,'ADJ: ',F6.0,3X,
  *'RMS = ',F7.4)
C
   RETURN
   END
```

C.4.6 Depth at Top of Near-Zero Gradient Below Thermocline

```
   SUBROUTINE DEP4(DELX,SUR,BOT,ICT2,CD,CG,D3,GRAD,R,
   TOL,NI,*IB,IF,IR)
C
C **********
```

```
C
C  VALUE OF IR DETERMINES INTERVAL OVER WHICH RMS IS
C  COMPUTED.
C
C ***********
C
C
      DIMENSION D3(400),GRAD(400),CD(*),CG(*),XG(400)
      KEEP = BOT
C
      IF(IR.EQ.1) THEN
       BOT = CD(5)
       CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
       CALL RMS(XG,GRAD,ICT,R)
      END IF
C
C  CHECK FIRST TO SEE WHETHER TO ADD OR SUBTRACT
     DEPTHS
C
      ICNT = 0
      FIRST = CD(5)
      DINC = DELX
      R1 = R
      CD(5) = CD(5) + DINC
      CALL BUMP(CD,5,DINC,IB,1,IGO)
      IF(IGO.EQ.1) GO TO 199
C
C  FILL MODELED GRADIENT ARRAY WITH LINR USING
     NEW DEPTHS
C
      IF(IR.EQ.1) BOT = CD(5)
      CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
      CALL RMS(XG,GRAD,ICT2,R)
      ICNT = ICNT+1
C
      IF(ABS(R-R1).LT.TOL) GO TO 199
C
C       IF(R.LT.R1) GO TO 100       @ GOING RIGHT WAY
C       IF(R.GT.R1) GO TO 150       @ GOING WRONG WAY
        IF(R.LT.R1) GO TO 100
        IF(R.GT.R1) GO TO 150

C  ADJUST D4 BY ADDING DEPTHS
C
  100  IF = 0
  102  IF(ICNT.GT.NI) GO TO 199
       R1 = R
       CD(5) = CD(5) + DINC
```

```
      CALL BUMP(CD,5,DINC,IB,1,IGO)
      IF(IGO.EQ.1) GO TO 199
C
      IF(IR.EQ.1) BOT = CD(5)
      CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
      CALL RMS(XG,GRAD,ICT2,R)
      ICNT = ICNT+1
C
      IF(ABS(R-R1).LT.TOL) GO TO 199
      IF(R.LT.R1) GO TO 102
      IF(R.GT.R1.AND.IF.NE.4) THEN
        IF = IF+1
        CD(5) = CD(5) - DINC
        DINC = DINC/2.
        GO TO 102
      END IF
C
      GO TO 199
C
C   ADJUST D4 BY SUBSTRACTING DEPTHS
C
  150 IF = 0
  152 IF(ICNT.GT.NI) GO TO 199
        R1 = R
      CD(5) = CD(5) - DINC
      CALL BUMP(CD,5,DINC,IB,-1,IGO)
      IF(IGO.EQ.1) GO TO 199
C
      IF(IR.EQ.1) BOT = CD(5)
      CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
      CALL RMS(XG,GRAD,ICT2,R)
      ICNT = ICNT+1
C
      IF(ABS(R-R1).LT.TOL) GO TO 199
      IF(R.LT.R1) GO TO 152
      IF(R.GT.R1.AND.IF.NE.4) THEN
        IF = IF+1
        CD(5) = CD(5) + DINC
        DINC = DINC/2.
        GO TO 152
      END IF
C
        GO TO 199
C
  199 CONTINUE
C
        ADJ = FIRST - CD(5)
```

```
C     WRITE(6,605) ICNT,ADJ,R
 605 FORMAT(1X,'D4 INTERATIONS: ',I3,4X,'ADJ: ',F6.0,3X,
    *'RMS = ',F7.4)
C
C    IF IR FLAG = 1, CALL LINR ONCE MORE WITH TRUE VALUE FOR
C    BOTTOM
C
     IF(IR.EQ.1) THEN
      BOT = KEEP
      CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
     END IF
C
     RETURN
     END
*******************************************************
   SUBROUTINE DEP4T(DELX,SUR,BOT,ICT2,CD,CG,D3,GRAD,R,
  *TOL3,NI,D2,T2)
C
C**********
C
C ADJUST D4 (CD(5)) - DEPTH OF TOP OF NEAR-ZERO
   GRADIENT BELOW THRMCLN
C USE TEMP FOR RMS
C
C***********
C
C
   DIMENSION D3(400),GRAD(400),CD(*),CG(*),XG(400),
  *D2(401),T2(401),TM(401)
C
CCALCULATE INITIAL RMS IN TEMP SPACE
C
   ICT = ICT2+1
   CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
   TM(1) = T2(1)
   DO 29 L=2,ICT
 29 TM(L) = XG(L-1) * (D2(L) - D2(L-1)) + TM(L-1)
   CALL RMS(TM,T2,ICT,R)
C
CCHECK FIRST TO SEE WHETHER TO ADD OR SUBTRACT
   DEPTHS
C
```

```
      ICNT = 0
      FIRST = CD(5)
      DINC = DELX
      R1 = R
      CD(5) = CD(5) + DINC
      IF(CD(5).GE.CD(6)) THEN
      CD(5) = CD(5) - DINC
      GO TO 199
      END IF
C
C     FILL MODELED GRADIENT ARRAY WITH LINR USING
      NEW DEPTHS
C
      CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
      TM(1) = T2(1)
      DO 30 L=2,ICT
   30 TM(L) = XG(L-1) * (D2(L) - D2(L-1)) + TM(L-1)
      CALL RMS(TM,T2,ICT,R)
      ICNT = ICNT+1
C
      IF(ABS(R-R1).LT.TOL3) GO TO 199
C
C      IF(R.LT.R1) GO TO 100       @ GOING RIGHT WAY
C      IF(R.GT.R1) GO TO 150       @ GOING WRONG WAY
       IF(R.LT.R1) GO TO 100
       IF(R.GT.R1) GO TO 150
C
C     ADJUST D4 BY ADDING DEPTHS
C
   100 IF = 0
   102 IF(ICNT.GT.NI) GO TO 199
         R1 = R
         CD(5) = CD(5) + DINC
         IF(CD(5).GE.CD(6)) THEN
        CD(5) = CD(5) - DINC
        GO TO 199
        END IF
C
      CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
      TM(1) = T2(1)
      DO 31 L=2,ICT
   31 TM(L) = XG(L-1) * (D2(L) - D2(L-1)) + TM(L-1)
      CALL RMS(TM,T2,ICT,R)
      ICNT = ICNT+1
```

```
C
    IF(ABS(R-R1).LT.TOL3) GO TO 199
    IF(R.LT.R1) GO TO 102
    IF(R.GT.R1.AND.IF.NE.4) THEN
    IF = IF+1
    CD(5) = CD(5) - DINC
    DINC = DINC/2.
    GO TO 102
   END IF
C
   GO TO 199
C
C ADJUST D4 BY SUBSTRACTING DEPTHS
C
  150 IF = 0
  152 IF(ICNT.GT.NI) GO TO 199
       R1 = R
       CD(5) = CD(5) - DINC
       IF(CD(5).LE.CD(4)) THEN
       CD(5) = CD(5) + DINC
      GO TO 199
     END IF
C
    CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
    TM(1) = T2(1)
    DO 32 L=2,ICT
 32 TM(L) = XG(L-1) * (D2(L) - D2(L-1)) + TM(L-1)
    CALL RMS(TM,T2,ICT,R)
    ICNT = ICNT+1
C
       IF(ABS(R-R1).LT.TOL3) GO TO 199
       IF(R.LT.R1) GO TO 152
       IF(R.GT.R1.AND.IF.NE.4) THEN
       IF = IF+1
       CD(5) = CD(5) + DINC
      DINC = DINC/2.
      GO TO 152
      END IF
C
       GO TO 199
C
 199 CONTINUE
C
       ADJ = FIRST - CD(5)
C     WRITE(6,605) ICNT,ADJ,R
  605 FORMAT(1X,'D4T INTERATIONS: ',I3,4X,'ADJ: ',F6.0,3X,
     *'RMS = ',F7.4)
C
     RETURN
     END
```

C.4.7 Depth between Two Last Legs of Profile

```
      SUBROUTINE DEP5(DELX,SUR,BOT,ICT2,CD,CG,D3,GRAD,R,TOL,NI,
     *IB,IF)
C
C **********
C
C ADJUST D5 (CD(6)) - DEPTH BETWEEN LAST TWO LEGS OF PROFILE
C
C ***********
C
C
      DIMENSION D3(400),GRAD(400),CD(*),CG(*),XG(400)
C
C CHECK FIRST TO SEE WHETHER TO ADD OR SUBTRACT DEPTHS
C
      ICNT = 0
      FIRST = CD(6)
      DINC = DELX
      R1 = R
      CD(6) = CD(6) + DINC
      CALL BUMP(CD,6,DINC,IB,1,IGO)
      IF(IGO.EQ.1) GO TO 199
C
C FILL MODELED GRADIENT ARRAY WITH LINR USING NEW DEPTHS
C
        CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
        CALL RMS(XG,GRAD,ICT2,R)
        ICNT = ICNT+1
C
        IF(ABS(R-R1).LT.TOL) GO TO 199
C
C       IF(R.LT.R1) GO TO 100    @ GOING RIGHT WAY
C       IF(R.GT.R1) THEN    @ GOING WRONG WAY
        IF(R.LT.R1) GO TO 100
        IF(R.GT.R1) THEN
C
        CD(6) = CD(6) - DINC
        R = R1
       GO TO 150
       END IF
C
C ADJUST D4 BY ADDING DEPTHS
C
  100 IF = 0
```

```
  102 IF(ICNT.GT.NI) GO TO 199
      R1 = R
      CD(6) = CD(6) + DINC
      CALL BUMP(CD,6,DINC,IB,1,IGO)
      IF(IGO.EQ.1) GO TO 199
C
      CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
      CALL RMS(XG,GRAD,ICT2,R)
      ICNT = ICNT+1
C
      IF(ABS(R-R1).LT.TOL) GO TO 199
      IF(R.LT.R1) GO TO 102
      IF(R.GT.R1.AND.IF.NE.10) THEN
      IF = IF+1
      CD(6) = CD(6) - DINC
      DINC = DINC/2.
      R = R1
      GO TO 102
      END IF

C
      GO TO 199
C
C ADJUST D4 BY SUBSTRACTING DEPTHS
C
  150 IF = 0
  152 IF(ICNT.GT.NI) GO TO 199
      R1 = R
      CD(6) = CD(6) - DINC
      CALL BUMP(CD,6,DINC,IB,-1,IGO)
      IF(IGO.EQ.1) GO TO 199
C
      CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
      CALL RMS(XG,GRAD,ICT2,R)
      ICNT = ICNT+1
C
      IF(ABS(R-R1).LT.TOL) GO TO 199
      IF(R.LT.R1) GO TO 152
      IF(R.GT.R1.AND.IF.NE.10) THEN
      IF = IF+1
      CD(6) = CD(6) + DINC
      DINC = DINC/2.
      R = R1
      GO TO 152
      END IF
```

```
C
      GO TO 199
C
 199 CONTINUE
C
      ADJ = FIRST - CD(6)
C     WRITE(6,605) ICNT,ADJ,R
 605  FORMAT(1X,'D4 INTERATIONS: ',I3,4X,'ADJ: ',F6.0,3X,
     *'RMS = ',F7.4)
C
      RETURN
      END
```

C.4.8 Adjustment of Bottom Gradient

```
   SUBROUTINE
   *GRAD3A(DELX,SUR,BOT,ICT2,CD,CG,D3,GRAD,R,TOL2,NI)
C
C *********
C
C SUBROUTINE GRAD3A
C ADJUST G3A - GRADIENT AT BOTTOM
C
C *********
C
   DIMENSION D3(400),GRAD(400),CD(*),CG(*),XG(400)
C
C CHECK FIRST TO SEE WHETHER TO ADD OR SUBTRACT
   GRADIENT
C
   FIRST = CG(5)
   GINC = FIRST/25.
   IF(GINC.LT.0.005) GINC = .005
   ICNT = 0
   R1 = R
   CG(5) = CG(5) + GINC
C
C  FILL MODELED GRADIENT ARRAY WITH LINR USING NEW
C  GRADIENT
C
    CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
    CALL RMS(XG,GRAD,ICT2,R)
    ICNT = ICNT+1
C
    IF(ABS(R-R1).LT.TOL2) GO TO 199
```

```
C
C   IF(R.LT.R1) GO TO 100 @      GOING RIGHT WAY
C   IF(R.GT.R1) THEN @      GOING WRONG WAY
      IF(R.LT.R1) GO TO 100
      IF(R.GT.R1) THEN
C
      CG(5) = CG(5) - GINC
      R = R1
      GO TO 150
      END IF

C
C ADJUST GRADIENT G3A BY ADDING
C
  100 IF = 0
  102 IF(ICNT.GT.NI) GO TO 199
        R1 = R
        CG(5) = CG(5) + GINC
C
        CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
        CALL RMS(XG,GRAD,ICT2,R)
        ICNT = ICNT+1
C
        IF(ABS(R-R1).LT.TOL2) GO TO 199
        IF(R.LT.R1) GO TO 102
        IF(R.GT.R1.AND.IF.NE.10) THEN
        IF = IF+1
        CG(5) = CG(5) - GINC
        GINC = GINC/2.
        R = R1
        GO TO 102
        END IF
C
C  GO TO 199
C
C  ADJUST GRADIENT G3A BY SUBTRACTING
C
  150 IF = 0
  152 IF(ICNT.GT.NI) GO TO 199
        R1 = R
        CG(5) = CG(5) - GINC
C
        CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
        CALL RMS(XG,GRAD,ICT2,R)
        ICNT = ICNT+1
```

```
C
      IF(ABS(R-R1).LT.TOL2) GO TO 199
      IF(R.LT.R1) GO TO 152
      IF(R.GT.R1.AND.IF.NE.10) THEN
      IF = IF+1
     CG(5) = CG(5) + GINC
      GINC = GINC/2.
      R = R1
      GO TO 152
      END IF
C
      GO TO 199
C
 199 CONTINUE
C
      ADJ = FIRST - CG(5)
C     WRITE(6,605) ICNT,ADJ,R
 605 FORMAT(1X,'GRAD3A ITERATIONS: ',I3,4X,'ADJ: ',F6.0,3X,
     *'RMS = ',F7.4)
C
     RETURN
     END

**************************************************
   SUBROUTINE
   *G3AT(DELX,SUR,BOT,ICT2,CD,CG,D3,GRAD,R,TOL3,NI,D2,T2)
C
C  *********
C
C  SUBROUTINE G3AT
C  ADJUST G3A - GRADIENT AT BOTTOM
C  DO RMS WITH TEMP INSTEDAD OF GRADIENT
C
C  *********
C
      DIMENSION D3(400),GRAD(400),CD(*),CG(*),XG(400),
      *D2(401),T2(401),TM(401)
C
C  CHECK FIRST TO SEE WHETHER TO ADD OR SUBTRACT
    GRADIENT
C
      ICT = ICT2+1
      GINC = CG(5)/25.
      IF(GINC.LT.0.0005) GINC = .0005
      FIRST = CG(5)
```

```
      ICNT = 0
      CG(5) = CG(5) + GINC
C
C     FILL MODELED GRADIENT ARRAY WITH LINR USING NEW
C     GRADIENT
C
      CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
      TM(1) = T2(1)
      DO 30 L=2,ICT
   30 TM(L) = XG(L-1) * (D2(L) - D2(L-1)) + TM(L-1)
      CALL RMS(TM,T2,ICT,R)
      ICNT = ICNT+1
       R1 = R
C
     IF(ABS(R-R1).LT.TOL3) GO TO 199
C
C      IF(R.LT.R1) GO TO 100 @ GOING RIGHT WAY
C      IF(R.GT.R1) THEN @ GOING WRONG WAY
     if(r.lt.r1) go to 100
     if(r.gt.r1) then
c
        CG(5) = CG(5) - GINC
        R = R1
        GO TO 150
     END IF
C
C  ADJUST GRADIENT G3A BY ADDING
C
   100 IF = 0
   102 IF(ICNT.GT.NI) GO TO 199
     R1 = R
     CG(5) = CG(5) + GINC
C
     CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
     TM(1) = T2(1)
     DO 31 L=2,ICT
   31 TM(L) = XG(L-1) * (D2(L) - D2(L-1)) + TM(L-1)
     CALL RMS(TM,T2,ICT,R)
     ICNT = ICNT+1
C
     IF(ABS(R-R1).LT.TOL3) GO TO 199
     IF(R.LT.R1) GO TO 102
     IF(R.GT.R1.AND.IF.NE.6) THEN
      IF = IF+1
      CG(5) = CG(5) - GINC
      GINC = GINC/2.
```

```
      R = R1
      GO TO 102
    END IF
C
    GO TO 199
C
C  ADJUST GRADIENT G3A BY SUBTRACTING
C
  150 IF = 0
  152 IF(ICNT.GT.NI) GO TO 199
    R1 = R
    CG(5) = CG(5) - GINC
C
    CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
    TM(1) = T2(1)
    DO 32 L=2,ICT
  32 TM(L) = XG(L-1) * (D2(L) - D2(L-1)) + TM(L-1)
    CALL RMS(TM,T2,ICT,R)
    ICNT = ICNT+1
C
    IF(ABS(R-R1).LT.TOL3) GO TO 199
    IF(R.LT.R1) GO TO 152
    IF(R.GT.R1.AND.IF.NE.6) THEN
      IF = IF+1
      CG(5) = CG(5) + GINC
      GINC = GINC/2.
      R = R1
      GO TO 152
    END IF
C
    GO TO 199
C
  199 CONTINUE
C
    CALL LINR(DELX,7,SUR,BOT,ICT2,CD,CG,D3,XG)
    TM(1) = T2(1)
    DO 33 L=2,ICT
  33 TM(L) = XG(L-1) * (D2(L) - D2(L-1)) + TM(L-1)
    CALL RMS(TM,T2,ICT,R)
C
    ADJ = FIRST - CG(5)
C     WRITE(6,605) ICNT,ADJ,R
  605 FORMAT(1X,'G3AT ITERATIONS: ',I3,4X,'ADJ: ',F6.4,3X,
     *'RMS = ',F7.4)
C
    RETURN
    END
```

C.4.9 Data Input/Output

```
      SUBROUTINE INOUT4
      CHARACTER*25 FOUT4,FOUT5,FOUT8,FOUT9,FIN3,allcoef
      PRINT *,'ENTER FILE NAME FOR COEF FILE (for unit 4)'
      READ(5,99)FOUT4
      print *,'Enter file name for MATLAB use (unit 28)'
      read(5,99)allcoef
      PRINT *,'ENTER FILE NAME FOR RECONSTRUCTED COEF
     (for unit 7)'
      READ(5,99)FOUT5
      PRINT *,'ENTER FILE NAME FOR INPUT MASTER FILE'
      READ(5,99) FIN3
      PRINT *,'ENTER FILE NAME FOR ACCEPTED PROFILES'
      READ(5,99) FOUT8
      PRINT *,'ENTER FILE NAME FOR REJECT FILE'
      READ(5,99) FOUT9
   99 FORMAT(A25)
      OPEN(4,FILE=FOUT4,FORM='FORMATTED',STATUS=
     'UNKNOWN')
      OPEN(28,file=allcoef,form='formatted',status='unknown')
      OPEN(7,FILE=FOUT5,FORM='FORMATTED',STATUS=
     'UNKNOWN')
      OPEN(3,FILE=FIN3,FORM='UNFORMATTED',STATUS='OLD')
      OPEN(8,FILE=FOUT8,FORM='UNFORMATTED',STATUS=
     'UNKNOWN')
      OPEN(9,FILE=FOUT9,FORM='UNFORMATTED',STATUS=
     'UNKNOWN')
      RETURN
      END
```

D

Autocorrelation Matrix Calculated from (T, S) Profile Data

```
C PROGRAM corre.f (f77 corre.f -o corre; Running See corre.com)
C CALCULATE AUTOCORELATION MATRICES FROM
   PROFILE DATA.
C JAPAN/EAST SEA EXAMPLE
C Longitude 127.5E–142E(mx=(142-127.5)/(15/60)+1= 59)
C Latitude 32.5N–50N(my=( 50- 32.5)/(15/60)+1= 71)
C*******************************************************
         parameter (maxpts =141330 , mx=59,my=71,Lv=28)
         real covar(64,64), var1(64,64), var2(64,64)
         integer num(64,64)
         real corr(64,64)
         character obsfile*80,infile*80,ofil1*80,ofil2*80,ofil3*80
         dimension itimlg(64), idstlg(64),tobs(200),tmean(mx,my,Lv)
         dimension anomly(maxpts,1) ,tlmean(mx,my)
         common /LL/dlat(my),dlon(mx),grid1
         common // zlat(maxpts,1), zlon(maxpts,1), time(maxpts,1),
   1     lagdd(maxpts) , lagtt(maxpts),
   2     zlati,zloni,timei,jpt,numpts(64),incdlg,inctlg,level
         crt=-50.0
         level = 1
         iloop = 0
C READ Parameter and FILE NAME
        print *,'Enter Layer-num: nk(1 or 2...or 28)'
        read(*,*) nk
c       print *,'obs.point filename'
         read(*,*)obsfile
c       print *,'grad.point filename'
        read(*,*)infile
        read(*,*)ofil1
        read(*,*)ofil2
        read(*,*)ofil3
```

```
C  OPEN THE INPUT FILE
       open(3,FILE=obsfile,form='formatted',STATUS='old')
       open(4,FILE=infile,form='formatted',STATUS='old')
       open(15,FILE='corrin.dat',form='formatted',STATUS='old')
C OPEN THE OUTPUT FILE.
            n=0
       open(16,FILE=ofil1,form='formatted', STATUS='unknown')
       open(17,file=ofil2,form='formatted', STATUS='unknown')
       open(18,file=ofil3,form='formatted', STATUS='unknown')
C READ IN THE MAXIMUM TIME(day)/DISTANCE(km)
LAGS AND THE LAG INCREMENT.
C READ IN THE LAT/LON BOUNDS OF THE AREA.
C        mxtlag- maximum TIME(days) difference allowed column
C        inctlg- time difference bin size
C        mxdlag- maximum DISTANCE(km) difference allowed rows
C        incdlag- distance difference bin size
         read(15,*) mxtlag,inctlg,mxdlag,incdlg,ntb,ndb
C        ex.input 25(day) 1(day) 250(km) 10(km) from file corrin.dat
         numtbn = mxtlag / inctlg + 1
         if ( numtbn .gt. ntb) stop ' more than ntb time bins'
         numdbn = mxdlag / incdlg + 1
         if ( numdbn .gt. ndb) stop ' more than ndb distance bins'
         write(16,'(6i6)') mxtlag,inctlg,mxdlag,incdlg,numtbn,numdbn
C     READ IN TEMPERATURE PROFILE DATA FOR THE MEAN
         write(16,*)'input grad point filename',infile
         grid=15.0
         grid1=grid/60.
    do   100 j=1,my
    do   101 i=1,mx
         read(4,*) dlon(i),xla,(tmean(i,my-j+1,k),k=1,28)
 101     continue
         dlat(my-j+1)=xla
 100     continue
         write(16,120)dlon(1),dlon(mx),dlat(1),dlat(my),grid1,mx,my
         write(6,120)dlon(1),dlon(mx),dlat(1),dlat(my),grid1,mx,my
 120     format(' lonw lone lats latn grid mx my'/,5f7.2,2i4)
         Idepth = 1
C        LOOP TO STORE TIME, PLACE, AND TEMPERATURE
         ANOMALY
C        VALUE.
C        Reads in the data from tbin as formatted in it.
         write(16,*)' input obser. point filename',obsfile
C        zero mean calc arrays
         do level=1,1
           numpts(level) = 0
```

```
      do ix=1,mx
       do iy=1,my
          lmean(ix,iy)= tmean(ix,iy,nk)
        Enddo
      Enddo
10    CALL READER(rlon,rlat,tobs,ILOOP,iyr,im,id,obsfile)
        if (iloop .eq. 0) go to 11
        CALL LMEAN(tm,rlon,rlat,tlmean,crt)
C       DETERMINE JULIAN DAY AND REAL-VALUED TIME
C       OF TEMPERATURE VALUE.
C       Type II = jday //// Type III = jday+(iyr*365)
        call juldat(iyr,im,id,jday)
        tmptim = jday
        write(16,165) rlon,rlat,tmptim
 165       format(' rlon,rlat= ',2f9.3,' tmptim =',f12.2)
C       TAKE THE OBSERVED TEMPERATURE (tobs) AND
        SUBTRACT
C       THE MEAN
C       TEMPERATURE(tmean) OUT TO GET THE ANOMOLY
        (anomly)
C       STORE THE POSITION, TIME, AND VALUE.
        if( tobs(1) .lt. 900. .and. tm .gt. crt) then
        numpts(level) = numpts(level) + 1
          n = numpts(level)
          if ( n .gt. maxpts ) stop ' too many points to store!'
          zlat(n,level) = rlat
          zlon(n,level) = rlon
          time(n,level) = tmptim
          anomly(n,level) = tobs(1) - tm
         write(16,160) tm,iloop,tobs(1),anomly(n,level)
          endif
          go to 10
        enddo
11       continue
160    format('t local mean=',f8.3,' tobs',i7,'=',f8.3,' 2T.Diff=',f9.3)
      print *,'level/n=',level,n,numpts(level)
       write(16,*)'completed input from',obsfile
      print *,'completed input from',obsfile
C     DETERMINE THE COVARIANCE, VARIANCE, AND
C     COUNTER ARRAYS.
C     ANY LAGS OUTSIDE THE BIN BOUNDARIES GO INTO
      A "SPARE"
C     ROW AND COLUMN
      do level =1,1,1
```

```
C INITIALIZE THE ARRAYS TO ZERO.
                ndbnp1 = numdbn + 1
                ptntbnp1 = numtbn + 1
              do lagt=1,ntbnp1
                            do lagd=1,ndbnp1
                            covar(lagd,lagt) = 0.
                            var1(lagd,lagt) = 0.
                  var2(lagd,lagt) = 0.
                              num(lagd,lagt) = 0
            corr(lagd,lagt)= 0.
              end do
                end do
                numcmp = 0
     do ipt=1,numpts(level)-1
           anomi = anomly(ipt,level)
           zlati = zlat(ipt,level)
           zloni = zlon(ipt,level)
           timei = time(ipt,level)
           jpt = ipt + 1
        call tdsep
     do jpt=ipt+1,numpts(level)
          numcmp = numcmp + 1
           lagd = min0 ( lagdd(jpt) , ndbnp1 )
           lagt = min0 ( lagtt(jpt) , ntbnp1 )
           anomj = anomly(jpt,level)
           covar(lagd,lagt) = covar(lagd,lagt) + anomi * anomj
           var1(lagd,lagt) = var1(lagd,lagt) + anomi * anomi
           var2(lagd,lagt) = var2(lagd,lagt) + anomj * anomj
           num(lagd,lagt) = num(lagd,lagt) + 1
      end do
      end do
C     FOR EACH ELEMENT OF THE COVARIANCE AND
      VARIANCE
C     ARRAYS, DIVIDE THROUGH
C     BY THE NUMBER OF VALUES USED IN THE
      SUMMATIONS.
C     THEN CALCULATE THE CORRELATION MATRIX.
         lagtmx = 0
         lagdmx = 0
         nmax = 0
         do lagt=1,numtbn
          itimlg(lagt) = ( lagt - 1 ) * inctlg
```

```
          do lagd=1,numdbn
           n = num(lagd,lagt)
           if ( n .ne. 0 ) then
            covar(lagd,lagt) = covar(lagd,lagt) / n
            var1(lagd,lagt) = var1(lagd,lagt) / n
            var2(lagd,lagt) = var2(lagd,lagt) / n
            corr(lagd,lagt) = covar(lagd,lagt) /
     *      ( sqrt ( var1(lagd,lagt) * var2(lagd,lagt) ) )
             endif
            idstlg(lagd) = ( lagd - 1 ) * incdlg
            end do
           end do
C WRITE OUT THE CORRELATION MATRIX IN A MATRIX
  FORMAT.
          write(17,'(i4,35i6)') itimlg(1),(itimlg(i),i=1,numtbn)
          do lagd=1,numdbn
          write(17,'(i4,35f6.2)') idstlg(lagd),
     *    (corr(lagd,lagt),lagt=1,numtbn)
          end do
         close(17)

C    WRITE OUT THE MATRIX CONTAINING THE NUMBER OF
C    PAIRS COMPARED IN
C    EACH BIN. THE VALUES ARE SCALED TO 10.
          if ( nmax .lt. 9999 ) then
           scale = 1.
           else
           scale = 9999. / nmax
          endif
          do lagt=1,numtbn
          do lagd=1,numdbn
          num(lagd,lagt) = nint ( num(lagd,lagt) * scale )
          end do
         end do
         write(18,'(i4,35i6)') itimlg(1),(itimlg(i),i=1,numtbn)
         do lagd=1,numdbn
         write(18,'(i4,35i6)') idstlg(lagd),
     *    (num(lagd,lagt),lagt=1,numtbn)
         end do
       end do
1000  continue
       print *,'n/nmax/scale=',n,nmax,scale
      close(18)
        stop ' normal end '
      end
```

```
c
*******************************************************
      SUBROUTINE tdsep
         parameter ( maxpts =141330)
         common // zlat(maxpts,1), zlon(maxpts,1), time(maxpts,1),
     1       lagdd(maxpts) , lagtt(maxpts),
     2       xla1,xlo1,timei,jpt,numpts(64),incdlg,inctlg,level
         data pi/3.1415927/
         data rad/.0174533/
         data deg/57.29578/
      data ert/6371.2/
      A=XLA1*RAD
        COSA=COS(A)
        SINA=SIN(A)
      do 10 kpt=jpt,numpts(level)
       B=zlat(kpt,level)*RAD
        CC=ABS(zlon(kpt,level)-XLO1)*RAD
        AMB=ABS(A-B)
        IF(AMB.GT.RAD.AND.CC.GT.RAD) GO TO 15
        XMLAT=(A+B)/2.
        DELY=AMB
        DELX=CC*COS(XMLAT)
        C=SQRT(DELX**2.+DELY**2.)
        GO TO 20
   15   IF(CC.GT.PI) CC=2.*PI-CC
        COSB=COS(B)
        SINB=SIN(B)
        COSCC=COS(CC)
        COSC=sina*sinb+cosa*cosb*COSCC
        SINC=SQRT(1.-COSC**2.)
        C=ASIN(SINC)
        IF(COSC.LT.0.0) C=PI-C
   20  CDEG=C*ert
        distnc=CDEG
        lagdd(kpt) = nint ( distnc / incdlg ) + 1
       lagtt(kpt) = nint(abs (timei - time(kpt,level)) /inctlg) +1
   10  continue
        RETURN
        END
```

```
C*************************************************************
*
      SUBROUTINE LMEAN(tm,x,y,tlmean,crv)
      parameter(mx= 59,my=71)
c          tm =mean used for tobs
c          x = rlon y = rlat
       dimension tlmean(mx,my),ff(4),xx(4),yy(4)
       common /LL/dlat(my),dlon(mx),grid
c   Find the mean temp value corresponding to x,y
       ii=(x-dlon(1))/grid+1
       jj=(y-dlat(1))/grid+1
       if(ii.gt.mx.or.jj.gt.my) then
       print*,'II,JJ EXCEED LIMIT!!! ===>RETURN'
       return
       endif
       xx(1)=dlon(ii)
       yy(1)=dlat(jj)
       ff(1)=tlmean(ii,jj)
       xx(2)=xx(1)
       yy(2)=dlat(jj+1)
       ff(2)=tlmean(ii,jj+1)
       xx(3)=dlon(ii+1)
       yy(3)=yy(2)
       ff(3)=tlmean(ii+1,jj+1)
       xx(4)=xx(3)
       yy(4)=yy(1)
       ff(4)=tlmean(ii+1,jj)
       call BLINT(xx,yy,ff,4,x,y,tm,crv)
       return
       end
C*************************************************************
      subroutine blint(xx,yy,ff,n,x,y,f,Z)
      dimension ff(n),xx(n),yy(n)
C   Bilinear interpolation subroutine.
C   (Xi,Yi,fi) = data grid & values surounding model point (x,y)
C   f = interpolated value at the model grid point.
```

```
  if(ff(1).ge.Z.and.ff(2).ge.Z.and.ff(3).ge.Z.and.ff(4).ge.Z)then
    a1=xx(1)-xx(2)+xx(3)-xx(4)
    a2=-xx(1)+xx(4)
    a3=-xx(1)+xx(2)
    a4=xx(1)-x
    b1=yy(1)-yy(2)+yy(3)-yy(4)
    b2=-yy(1)+yy(4)
    b3=-yy(1)+yy(2)
    b4=yy(1)-y
    A=a3*b1-a1*b3
    B=b2*a3+b1*a4-a1*b4-a2*b3
    C=-a2*b4+a4*b2
    if(ABS(A*C).gt.0.002*B**2) then
      t=(-B-sqrt(B*B-4.*A*C))/(2.*A)
      else
         t=C/ABS(B)
    endif
10   continue
    A=a2*b1-a1*b2
    B=b3*a2+b1*a4-a1*b4-a3*b2
    C=-a3*b4+a4*b3
    if(ABS(A*C).gt.0.002*B**2) then
       s=(-B+sqrt(B*B-4.*A*C))/(2.*A)
       else
          s=-C/abs(B)
    endif
20   continue
    f=ff(1)*(1.-t)*(1.-s)+ff(2)*t*(1.-s)+ff(3)*s*t+ff(4)*(1.-t)*s
    else
     rmn=0.0
     fmn=0.0
     do i=1,n
      if(ff(i).ge.Z) then
       rrr=1./(1.0e-20+(x-xx(i))**2+(y-yy(i))**2)
       rmn=rmn+rrr
       fmn=fmn+ff(i)*rrr
      endif
    enddo
    if(rmn.gt.0.0) then
     f=fmn/rmn
    else
     f=-99.99
    endif
   endif
```

```
C   .....................................................
    return
    end
C ------------------------------------------------------
     SUBROUTINE JULDAT(IYR,IMO,IDAY,JULD)
C SUBR TO CALCULATE THE JULIAN DATE
C ACCOUNTS FOR LEAP YEARS
C INPUTS: IYR - YEAR (INTEGER 0 TO 99)
C         IMO - MONTH (INTEGER 1 TO 12)
C        IDAY - DAY (INTEGER (1 TO LAST DAY OF MONTH)
C OUTPUTS: JULD - JULIAN DATE (1 TO 365/366 FOR LEAP
   YEAR)
C VARIABLES:
C        MON (12) - DAYS IN EACH MONTH
C.....................................................
    DIMENSION MON(12)
    DATA MON /31,28,31,30,31,30,31,31,30,31,30,31/
    MON(2) = 28
C CHECK FOR LEAP YEAR
    IF (MOD(IYR,4) .EQ. 0 .AND. IYR .NE. 0) MON(2) = 29
    JULD = 0
    IF (IMO .EQ. 1) GOTO 120
    DO 100 K = 1, IMO-1
     JULD = JULD + MON(K)
100 CONTINUE
120 CONTINUE
     JULD = JULD + IDAY
     ym=iyr-1930
     ly=ym/4.0
    ily=ifix(ly)
    juld=juld+ym*365+ily
    RETURN
    END
    SUBROUTINE READER(X,Y,TEMP,ILOOP,iy,im,id,INFILE)
C *******************************************************
C *            SUBROUTINE READER2                       *
C *      READS TEMPS AT SPECIFIED PCT OF DBDB5   *
C *              FOR CHRTR                    *
C *******************************************************
```

```
C   INTERFACES TO CHRTR
C   THIS SUBROUTINE READS TEMPERATURE (OR SALINITY)
C   PROFILES.
C   THE TEMP AT A USER SPECIFIED PCT DEPTH, AND PASSES
    THE
C   LAT, LON, AND TEMP BACK TO PROGRAM CHRTR FOR
C   SUBSEQUENT GRIDDING.
C   VARIABLE WDEP2 IS DBDB5 DEPTH. XDEPTH IS DEPTH
    THAT TEMP
C   IS PICKED OFF (VERTICALLY INTERPOLATED) FROM EACH
    MOODS
C   PROFILE.
C   XDEPTH WILL BE DIFFERENT FOR EACH PROFILE,
    DEPENDING ON
C   WATER DEPTH (AS DETERMINED FROM DBDB5).
    NOTE THAT
C   DBDB5 WAS NEVER MEANT TO BE USED IN
    SHALLOW WATER,
C   THUS THE USER IS RESPONSIBLE TO UNDERSTAND ITS
C   LIMITATIONS IN THE SPECIFIC ANALYSIS REGION.
C
    CHARACTER infile*80
    DIMENSION TEMP(200)
C   FIRST TIME READER9 IS CALLED, SPECIFY AND OPEN
    INPUT FILE
     if(iloop.eq.0) then
           write(16,*)'opening ',infile
     close(3)
     open(3,FILE=infile,form='formatted',STATUS='old')
     read(3,*)lev
     write(6,600)lev
     write(16,600)lev
  600 format(1x,'what level (depth of water column)?',i4)
     endif
     iloop = iloop+1
C        READ PROFILE FROM MASTER FILE -
    5 continue
      READ(3,*,END=99) XLAT,XLON,t,iy,im,id
       Y = XLAT
       X = XLON
       TEMP(1) = T
       RETURN
   99 continue
       iloop = 0
       return
       END
```

```
**************************************************
      SUBROUTINE LINR(DELX,N,XBGN,XEND,ICT,X,Y,AX,AY)
C     LINEAR INTERPOLATOR ROUTINE FOR USE WHEN SPLINE
C     IS NOT APPROPRIATE
C     IE.LARGE GAPS IN INPUT DATA NEAR SHARP CHANGES IN
C     GRADIENT WITH LOCALLY INADEQUATE SAMPLING.
C     DELX=DESIRED INTERPOLATION INTERVAL,X AND Y ARE
      INPUT
C     WITH X=INDEP.
C     VARIABLE,AX AND AY ARE OUTPUT,N=LENGTH OF X,
      XBGN AND
C     XEND=DESIRED
C     BEGINNING AND ENDING VALUES OF AX,ICT=LENGTH OF AX
      DIMENSION X(*),Y(*),AX(*),AY(*)
      NN=N-1
      ICT=((XEND-XBGN)/DELX)+1.0001
      DO 1 J=1,ICT
      A=J-1
    1 AX(J)=A*DELX+XBGN
      KK=1
      DO 2 J=1,NN
      JJ=J+1
      SLOPE=(Y(JJ)-Y(J))/(X(JJ)-X(J))
      DO 3 K=KK,ICT
      I=K
      IF(AX(K).GT.X(JJ).AND.AX(K).LE.X(N)) GO TO 2
    3 AY(K)=SLOPE*(AX(K)-X(J))+Y(J)
      GO TO 4
    2 KK=I
    4 RETURN
      END
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