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AN AXISYMMETRIC NUMERICAL MODEL FOR A NON-HYDROSTATIC
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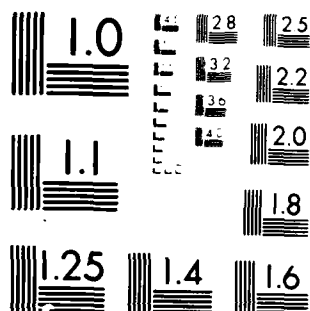
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NRL Memorandum Report 4957

**An Axisymmetric, Numerical Model for a
Non-Hydrostatic Boussinesq Ocean**

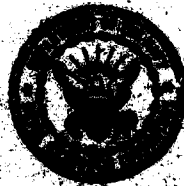
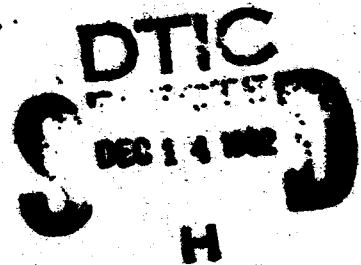
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report documents an axisymmetric, non-hydrostatic ocean model. The governing equations are first presented, and the finite difference (FD) form of the governing equations are developed for the fully staggered grid. The elliptic diagnostic equation for pressure is then derived and the associated boundary conditions are discussed. A listing of the FORTRAN codes of the model and a hydrostatic version of the model are attached. This model is useful for studies such as ocean response to circular wind fields or the secondary flow within Gulf Stream rings.		

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AN AXISYMMETRIC, NUMERICAL MODEL FOR A NON-HYDROSTATIC BOUSSINESQ OCEAN

1. GOVERNING EQUATIONS

The governing equations of the axisymmetric, non-hydrostatic, Boussinesq ocean model are

$$\begin{aligned} \frac{\partial u}{\partial t} + u \frac{\partial u}{\partial r} + w \frac{\partial u}{\partial z} = \frac{v^2}{r} + fv - \frac{1}{\rho_0} \frac{\partial p}{\partial r} + K_H \left(\nabla^2 u - \frac{u}{r^2} \right) \\ + K_z \frac{\partial^2 u}{\partial z^2} \end{aligned} \quad (1-1)$$

$$\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial r} + w \frac{\partial v}{\partial z} = - \frac{uv}{r} - fu + K_H \left(\nabla^2 v - \frac{v}{r^2} \right) + K_z \frac{\partial^2 v}{\partial z^2} \quad (1-2)$$

$$\frac{\partial w}{\partial t} + u \frac{\partial w}{\partial r} + w \frac{\partial w}{\partial z} = -b - \frac{1}{\rho_0} \frac{\partial p}{\partial z} + K_H \nabla^2 w + K_z \frac{\partial^2 w}{\partial z^2} \quad (1-3)$$

$$\frac{\partial b}{\partial t} + u \frac{\partial b}{\partial r} + w \frac{\partial b}{\partial z} = N_z^2 w + K_H \nabla^2 b + K_z \frac{\partial^2 b}{\partial z^2} \quad (1-4)$$

where $\nabla^2 \equiv \frac{\partial^2}{\partial r^2} + \frac{1}{r} \frac{\partial}{\partial r}$, other symbols are listed in Appendix A.

Above, the density anomaly b is defined according to

$$b = \frac{\rho - \rho_r(z)}{\rho_0} g, \quad (1-5)$$

where $\rho_r(z)$ is a reference density and is a function of depth only. Brunt-Väisälä frequency N_z is defined as

$$N_z = \sqrt{\left(\frac{-g}{\rho_0} \frac{\partial \rho_r}{\partial z} \right)} \quad (1-6)$$

The continuity equation is that of the incompressible fluid,

$$\frac{1}{r} \frac{\partial ur}{\partial r} + \frac{\partial w}{\partial z} = 0 \quad (1-7)$$

2. THE MODEL GRID

It is determined that a fully staggered grid is most expedient for storage economy for a given spatial resolution. As shown in Fig. 1, the radial (u) and the tangential (v) velocities are defined at cross points, vertical velocities (w) are defined at open circle points, and the pressures (p) and density anomalies (b) are defined at blackened dot points. This grid system has the following advantages:

- a) it saves storage for a given spatial resolution
- b) it is very economical in terms of number of computational operations for the finite difference (FD) equations of (1-1) to (1-4).
- c) it is very easy to specify the boundary conditions,
- d) the pressure diagnostic equation, of the elliptic type, can be reduced to the standard form, and
- e) there is no spatial separation of solutions on the grid.

In order to consistently index the grid points, we let index pair (ij) represent the i -th point in the r -direction and j -th point in the z -direction. In addition, m is the maximum number of points in the r -direction, and n , the maximum number of points in the z -direction. Therefore there are $m \times (n-1)$ points for radial and tangential velocities, $(m-1) \times n$ points for vertical velocities, and $(m-1) \times (n-1)$ points for mass distribution (b and p).

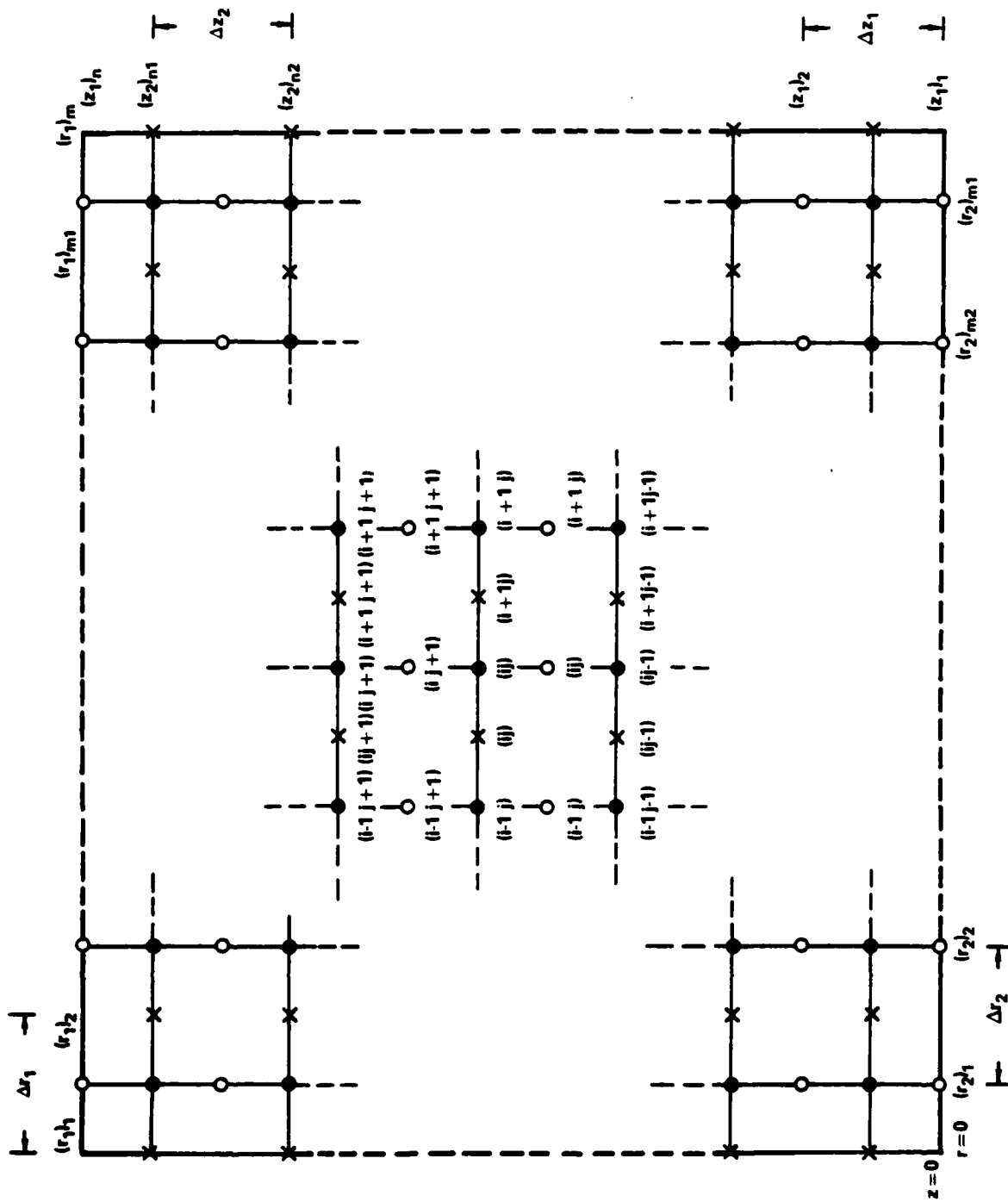


Fig. 1 The fully staggered grid system of the ocean model.

3. THE FINITE DIFFERENCE EQUATIONS

The leapfrog, or centered-in-time, integration scheme for the inviscid terms and the forward-in-time integration scheme for the viscous terms are used. The scheme is described as

$$\begin{pmatrix} u^{t+\Delta t} \\ v^{t+\Delta t} \\ w^{t+\Delta t} \\ b^{t+\Delta t} \end{pmatrix} = \begin{pmatrix} u^{t-\Delta t} \\ v^{t-\Delta t} \\ w^{t-\Delta t} \\ b^{t-\Delta t} \end{pmatrix} + 2\Delta t \begin{pmatrix} \frac{\partial u}{\partial t}^t \\ \frac{\partial v}{\partial t}^t \\ \frac{\partial w}{\partial t}^t \\ \frac{\partial b}{\partial t}^t \end{pmatrix} \quad (3-1)$$

A second order, or centered-in-space, scheme is applied to derive the tendencies in (3-1) according to (1-1) ~ (1-4).

(a) The Equation of Motion in r-direction

$$\frac{\partial u_{ij}^t}{\partial t} = H_{ij}^t - \frac{1}{c_0} \frac{1}{(\Delta r_2)_i} (p_{ij} - p_{i-1j}) \quad (3-2)$$

where

$$\begin{aligned}
H_{ij}^t = & -0.25 \left[\frac{1}{(\Delta r_1)_{i-1}} (u_{ij}^t + u_{i-1j}^t) (u_{ij}^t - u_{i-1j}^t) \right. \\
& + \frac{1}{(\Delta r_1)_i} (u_{i+1j}^t + u_{ij}^t) (u_{i+1j}^t - u_{ij}^t) \\
& + \frac{1}{(\Delta z_2)_j} (w_{i-1j}^t + w_{ij}^t) (u_{ij}^t - u_{ij-1}^t) \\
& \left. + \frac{1}{(\Delta z_2)_{j+1}} (w_{ij+1}^t + w_{i-1j+1}^t) (u_{ij+1}^t - u_{ij}^t) \right] \\
& + v_{ij}^t \left[\frac{v_{ij}^t}{(r_1)_i} + f \right] \\
& + K_H \left\{ \frac{1}{(\Delta r_2)_i} \left[\frac{1}{(\Delta r_1)_i} (u_{i+1j}^{t-\Delta t} - u_{ij}^{t-\Delta t}) \right. \right. \\
& \quad \left. \left. - \frac{1}{(\Delta r_1)_{i-1}} (u_{ij}^{t-\Delta t} - u_{i-1j}^{t-\Delta t}) \right] \right. \\
& + 0.5 \left[\frac{1}{(r_2)_i (\Delta r_1)_i} (u_{i+1j}^{t-\Delta t} - u_{ij}^{t-\Delta t}) \right. \\
& \quad \left. + \frac{1}{(r_2)_{i-1} (\Delta r_1)_{i-1}} (u_{ij}^{t-\Delta t} - u_{i-1j}^{t-\Delta t}) \right] \\
& \left. - \frac{u_{ij}^{t-\Delta t}}{(r_1)_i^2} \right\} + \frac{K_z}{(\Delta z_1)_j} \left[\frac{1}{(\Delta z_2)_{j+1}} (u_{ij+1}^{t-\Delta t} - u_{ij}^{t-\Delta t}) \right. \\
& \quad \left. - \frac{1}{(\Delta z_2)_j} (u_{ij}^{t-\Delta t} - u_{ij-1}^{t-\Delta t}) \right]
\end{aligned}$$

(3-5)

(b) The Equation of Motion in θ -direction

$$\begin{aligned}
 \frac{\partial v_{ij}^t}{\partial t} = & -0.25 \left[\frac{1}{(\Delta r_1)_{i-1}} (u_{ij}^t + u_{i-1j}^t) (v_{ij}^t - v_{i-1j}^t) \right. \\
 & + \frac{1}{(\Delta r_1)_i} (u_{i+1j}^t + u_{ij}^t) (v_{i+1j}^t - v_{ij}^t) \\
 & + \frac{1}{(\Delta z_2)_j} (w_{i-1j}^t + w_{ij}^t) (v_{ij}^t - v_{ij-1}^t) \\
 & \left. + \frac{1}{(\Delta z_2)_{j+1}} (w_{ij+1}^t + w_{i-1j+1}^t) (v_{ij+1}^t - v_{ij}^t) \right] \\
 & - u_{ij}^t \left[\frac{v_{ij}^t}{(r_1)_i} + f \right] \\
 & + \frac{K_H}{(\Delta r_2)_i} \left\{ \left[\frac{1}{(\Delta r_1)_i} (v_{i+1j}^{t-\Delta t} - v_{ij}^{t-\Delta t}) \right. \right. \\
 & \quad \left. \left. - \frac{1}{(\Delta r_1)_{i-1}} (v_{ij}^{t-\Delta t} - v_{i-1j}^{t-\Delta t}) \right] \right. \\
 & + 0.5 \left[\frac{1}{(r_2)_i (\Delta r_1)_i} (v_{i+1j}^{t-\Delta t} - v_{ij}^{t-\Delta t}) \right. \\
 & \quad \left. + \frac{1}{(r_2)_{i-1} (\Delta r_1)_{i-1}} (v_{ij}^{t-\Delta t} - v_{i-1j}^{t-\Delta t}) \right] \\
 & \left. - \frac{v_{ij}^{t-\Delta t}}{(r_1)_i^2} \right\} + \frac{K_z}{(\Delta z_1)_j} \left[\frac{1}{(\Delta z_2)_{j+1}} (v_{ij+1}^{t-\Delta t} - v_{ij}^{t-\Delta t}) \right. \\
 & \quad \left. - \frac{1}{(\Delta z_2)_j} (v_{ij}^{t-\Delta t} - v_{ij-1}^{t-\Delta t}) \right] \quad (3-4)
 \end{aligned}$$

(c) The Equation of Motion in z-direction

$$\frac{\partial w_{ij}^t}{\partial t} = G_{ij}^t - \frac{1}{c_0(\Delta z_2)_j} (p_{ij} - p_{ij-1}) \quad (5-5)$$

where

$$\begin{aligned} G_{ij}^t = & -0.25 \left[\frac{1}{(\Delta r_2)_i} (u_{ij}^t + u_{ij-1}^t) (w_{ij}^t - w_{i-1j}^t) \right. \\ & + \frac{1}{(\Delta r_2)_{i+1}} (u_{i+1j}^t + u_{i+1j-1}^t) (w_{i+1j}^t - w_{ij}^t) \\ & + \frac{1}{(\Delta z_1)_{j-1}} (w_{ij-1}^t + w_{ij}^t) (w_{ij}^t - w_{ij-1}^t) \\ & \left. + \frac{1}{(\Delta z_1)_j} (w_{ij+1}^t + w_{ij}^t) (w_{ij+1}^t - w_{ij}^t) \right] \\ & - 0.5 (b_{ij}^t + b_{ij-1}^t) \\ & + K_H \left\{ \frac{1}{(\Delta r_1)_i} \left[\frac{1}{(\Delta r_2)_{i+1}} (w_{i+1j}^{t-\Delta t} - w_{ij}^{t-\Delta t}) \right. \right. \\ & \quad \left. \left. - \frac{1}{(\Delta r_2)_i} (w_{ij}^{t-\Delta t} - w_{i-1j}^{t-\Delta t}) \right] \right. \\ & + 0.5 \left[\frac{1}{(r_1)_{i+1} (\Delta r_2)_{i+1}} (w_{i+1j}^{t-\Delta t} - w_{ij}^{t-\Delta t}) \right. \\ & \quad \left. \left. + \frac{1}{(r_1)_i (\Delta r_2)_i} (w_{ij}^{t-\Delta t} - w_{i-1j}^{t-\Delta t}) \right] \right\} \end{aligned}$$

$$+ \frac{K_z}{(\Delta z_2)_j} \left[\frac{1}{(\Delta z_1)_j} (w_{ij+1}^{t-\Delta t} - w_{ij}^{t-\Delta t}) - \frac{1}{(\Delta z_1)_{j-1}} (w_{ij}^{t-\Delta t} - w_{ij-1}^{t-\Delta t}) \right] \quad (5-6)$$

(d) The Thermodynamic Equation

$$\begin{aligned} \frac{\partial b_{ij}^t}{\partial t} = & -0.5 \left[\frac{u_{ij}^t}{(\Delta r_2)_i} (b_{ij}^t - b_{i-1j}^t) + \frac{u_{i+1j}^t}{(\Delta r_2)_{i+1}} (b_{i+1j}^t - b_{ij}^t) \right. \\ & + \frac{w_{ij}^t}{(\Delta z_2)_j} (b_{ij}^t - b_{ij-1}^t) + \left. \frac{w_{ij+1}^t}{(\Delta z_2)_{j+1}} (b_{ij+1}^t - b_{ij}^t) \right] \\ & + 0.5 (w_{ij+1}^t + w_{ij}^t) N_z^2 \\ & + K_H \left\{ \frac{1}{(\Delta r_1)_i} \left[\frac{1}{(\Delta r_2)_{i+1}} (b_{i+1j}^{t-\Delta t} - b_{ij}^{t-\Delta t}) \right. \right. \\ & \quad \left. \left. - \frac{1}{(\Delta r_2)_i} (b_{ij}^{t-\Delta t} - b_{i-1j}^{t-\Delta t}) \right] \right. \\ & + 0.5 \left[\frac{1}{(r_1)_{i+1} (\Delta r_2)_{i+1}} (b_{i+1j}^{t-\Delta t} - b_{ij}^{t-\Delta t}) \right. \\ & \quad \left. \left. + \frac{1}{(r_1)_i (\Delta r_2)_i} (b_{ij}^{t-\Delta t} - b_{i-1j}^{t-\Delta t}) \right] \right\} \\ & + \frac{K_z}{(\Delta z_1)_j} \left[\frac{1}{(\Delta z_2)_{j+1}} (b_{ij+1}^{t-\Delta t} - b_{ij}^{t-\Delta t}) \right. \\ & \quad \left. - \frac{1}{(\Delta z_2)_j} (b_{ij}^{t-\Delta t} - b_{ij-1}^{t-\Delta t}) \right] \end{aligned} \quad (5-7)$$

4. DERIVATION OF THE DIAGNOSTIC EQUATION FOR PRESSURE

The nonhydrostatic pressure at time t is needed to compute the pressure gradient forces in (3-2) and (3-5). To "recover" the pressure from the motion fields, we make use of the continuity equation by differentiating (1-7) with time we get

$$\frac{1}{r} \frac{\partial}{\partial r} r \frac{\partial u}{\partial t} + \frac{\partial}{\partial z} \frac{\partial w}{\partial t} = 0 ,$$

which can be written in finite difference form for a mass point ij as

$$\begin{aligned} & \frac{1}{\frac{1}{2} [(r_1)_i + (r_1)_{i+1}] (\Delta r_1)_i} \left[(r_1)_{i+1} \frac{\partial u_{i+1,j}^t}{\partial t} - (r_1)_i \frac{\partial u_{i,j}^t}{\partial t} \right] \\ & + \frac{1}{(\Delta z_1)_j} \left[\frac{\partial w_{i,j+1}^t}{\partial t} - \frac{\partial w_{i,j}^t}{\partial t} \right] = 0 \end{aligned} \quad (4-1)$$

$$\text{Let } c_i = (r_1)_{i+1} / \left\{ \frac{1}{2} [(r_1)_i + (r_1)_{i+1}] (\Delta r_1)_i \right\}, \quad (4-2)$$

$$\text{and } a_i = (r_1)_i / \left\{ \frac{1}{2} [(r_1)_i + (r_1)_{i+1}] (\Delta r_1)_i \right\}$$

Substituting (3-2), (3-5) and (4-2) into (4-1), we have

$$\begin{aligned}
c_i H_{i+1j}^t &= \frac{1}{\varepsilon_0} \frac{c_i}{(\Delta r_2)_{i+1}} (p_{i+1j} - p_{ij}) - a_i H_{ij}^t \\
&+ \frac{1}{\varepsilon_0} \frac{a_i}{(\Delta r_2)_i} (p_{ij} - p_{i-1j}) + \frac{1}{(\Delta z_1)_j} G_{ij+1}^t - \frac{1}{(\Delta z_1)_j} G_{ij}^t \\
&- \frac{1}{\varepsilon_0 (\Delta z_1)_j (\Delta z_2)_{j+1}} (p_{ij+1} - p_{ij}) \\
&+ \frac{1}{\varepsilon_0 (\Delta z_1)_j (\Delta z_2)_j} (p_{ij} - p_{ij-1}) = 0
\end{aligned}$$

After some rearrangements, we get

$$\begin{aligned}
&= \frac{c_i}{(\Delta r_2)_{i+1}} p_{i+1j} - \frac{a_i}{(\Delta r_2)_i} p_{i-1j} \\
&- \frac{1}{(\Delta z_1)_j (\Delta z_2)_j} p_{ij-1} - \frac{1}{(\Delta z_1)_j (\Delta z_2)_{j+1}} p_{ij+1} \\
&+ \left[\frac{c_i}{(\Delta r_2)_{i+1}} + \frac{a_i}{(\Delta r_2)_i} + \frac{1}{(\Delta z_1)_j (\Delta z_2)_{j+1}} + \frac{1}{(\Delta z_1)_j (\Delta z_2)_j} \right] p_{ij} \\
&= \varepsilon_0 \left[-c_i H_{i+1j}^t + a_i H_{ij}^t - \frac{1}{(\Delta z_1)_j} G_{ij+1}^t + \frac{1}{(\Delta z_1)_j} G_{ij}^t \right] \quad (4-5)
\end{aligned}$$

Now let $-F_{ij} = \text{RHS of (4-5)}$,

$$CX_i = \frac{c_i}{(\Delta r_2)_{i+1}} = (r_1)_{i+1} / \left\{ \frac{1}{2} [(r_1)_i + (r_1)_{i+1}] \right. \\ \left. (\Delta r_1)_i (\Delta r_2)_{i+1} \right\} ,$$

$$AX_i = \frac{a_i}{(\Delta r_2)_i} = (r_1)_i / \left\{ \frac{1}{2} [(r_1)_i + (r_1)_{i+1}] \right. \\ \left. (\Delta r_1)_i (\Delta r_2)_i \right\} ,$$

$$CZ_j = 1/[(\Delta z_1)_j (\Delta z_2)_{j+1}] ,$$

$$AZ_j = 1/[(\Delta z_1)_j (\Delta z_2)_j] , \text{ and}$$

$$BB_{ij} = - CX_i - AX_i - CZ_j - AZ_j \quad (4-4)$$

We obtain the standard form of an elliptic equation in FD form

$$AX_i P_{i-1j} + AZ_j P_{ij-1} + BB_{ij} P_{ij} + CX_i P_{i+1j} + CZ_j P_{ij+1} = F_{ij} \quad (4-5)$$

Equation (4-5) can be solved numerically by the SEVP solver (Madala, 1978), providing the boundary conditions are properly posed.

The conditions for the four boundaries are determined according to the following assumptions:

(a) At $(r_1)_i = (r_1)_1 = 0$, the natural condition for the cylindrical coordinates calls for $u = v = 0 = \partial u / \partial t = \partial v / \partial t$, the gradient balance requires that $(\partial P / \partial r)_{r=0} = 0$. Therefore an extra column of P is needed

$$P_{0j} = P_{1j} \quad (4-6)$$

(b) At $(r_1)_i = (r_1)_m$, assuming both the horizontal divergence and the vorticity are continuous, i.e., $\frac{\partial}{\partial r} \frac{1}{r} \frac{\partial ur}{\partial r} = 0$ and $\frac{\partial}{\partial r} \frac{1}{r} \frac{\partial vr}{\partial r} = 0$. These lead to

$$u_{mj} = b_a u_{m1j} + b_b [(r_1)_{m1} u_{m1j} - (r_1)_{m2} u_{m2j}] \quad (4-7)$$

$$v_{mj} = b_a v_{m1j} + b_b [(r_1)_{m1} v_{m1j} - (r_1)_{m2} v_{m2j}]$$

where $b_a = (r_1)_{m1} / (r_1)_m$, and

$$b_b = [(r_1)_{m1} + (r_1)_{m2}] (\Delta r_1)_{m1} / \{ (\Delta r_1)_{m2} [(r_1)_{m1} + (r_1)_{m2}] \}$$

Note that if b_b is set equal to zero, (4-7) describes a non-divergent and zero-vorticity boundary condition at $r = (r_1)_m$. Once v_{mj} is determined, a gradient balance at $r = (r_1)_m$ requires

$$\rho_0 v_{mj} \left[\frac{v_{mj}}{(r_1)_m} + f \right] = \frac{1}{(\Delta r_2)_m} (p_{mj} - p_{m-1j})$$

or

$$p_{mj} = p_{m-1j} + \rho_0 (\Delta r_2)_m v_{mj} \left[\frac{v_{mj}}{(r_1)_m} + f \right] \quad (4-8)$$

where a column of dummy points p_{mj} has been introduced for computational purposes. The second part of the RHS of (4-8) is thus the forcing function at $(r_1)_m$ for the elliptic equation (4-5).

(c) At the bottom, $w_{i1} = \frac{\partial}{\partial t} w_{i1} = 0$. Substituting these into the continuity equation (4-1), we get

$$\frac{1}{\frac{1}{2} (r_1)_i + (r_i)_{i+1} (\Delta r_1)_i} \left[(r_1)_{i+1} \frac{\partial u_{i+11}^t}{\partial t} - (r_1)_i \frac{\partial u_{i1}^t}{\partial t} \right] + \frac{1}{(\Delta z_1)_1} \frac{\partial w_{i2}^t}{\partial t} = 0. \quad (4-9)$$

Following the same deduction between (4-1) and (4-5), we get an expression similar to (4-5) with the second term on the LHS and G_{i1} in the RHS absent. Thus, P_{i1} can be obtained by the same SEVP solver by setting $CZ_1 = 0$ and $G_{i1} = 0$.

(d) At top $w_{in} = \frac{\partial}{\partial t} w_{in} = 0$. Following the same line of reasoning as in (c), we obtain P_{in} by solving (4-5) with $CZ_n P_{in+1} = 0$ and $G_{in} = 0$.

In summary, the elliptic pressure diagnostic equation (4-4) is to be solved with the following boundary conditions

- 1) At $r = 0$ $P_{0j} = P_{1j}$ i.e., (4-6)
- 2) At $r = (r_1)_m$ $P_{mj} = P_{m-1j} + \text{function } (v_{mj})$ (4-8)
- 3) At $z = 0$ $AZ_1 = 0$ and $G_{i1} = 0$
- 4) At $z = (z_1)_n$ $CZ_n = 0$ and $G_{in} = 0$

LIST OF SYMBOLS

AX_i	an array of constants, varying only in r-direction, defined by (4-4), used in (4-5)
Az_j	an array of constants, varying only in z-direction defined by (4-4), used in (4-5)
a_i	an array of constants related to r_1 and Δr_1 used in (4-2)
BB_{ij}	an array of constants, used in (4-5)
b	density anomalies, defined in (1-5), cm s^{-2}
CX_i	an array of constants, varying only in r-direction, defined by (4-4), used in (4-5)
Cz_j	an array of constants, varying only in z-direction, defined by (4-4), used in (4-5)
c_i	an array of constants, related to r_1 and Δr_1 , used in (4-5)
f	Coriolis parameter, s^{-1}
g	gravitational acceleration, cm s^{-2}
i	an index, denoting i-th point in r-direction
j	an index, denoting j-th point in z-direction
K_H	horizontal diffusion coefficient, $\text{cm}^2 \text{s}^{-1}$
K_z	vertical diffusion coefficient, $\text{cm}^2 \text{s}^{-1}$
LHS	left hand side
m	the maximum number of grid points in r-direction, upper bound of i

m_1	$m-1$
m_2	$m-2$
N_z	Brunt-Väisälä frequency, s^{-1}
n	the maximum number of grid points in z -direction, upper bound of j
n_1	$n-1$
n_2	$n-2$
p	pressure, dyne cm^{-2}
RHS	right hand side
r	radius, cm
r_1	radii of momentum points, cm
r_2	radii of mass points, cm
Δr_1	distance between two horizontally adjacent momentum points, cm
Δr_2	distance between two horizontally adjacent mass points, cm
SEVP	<u>s</u> tabilized <u>e</u> rror <u>v</u> ector <u>p</u> ropagation
t	time, s
Δt	time interval, s
u	radial velocity, $cm\ s^{-1}$
v	tangential velocity, $cm\ s^{-1}$
w	vertical velocity, $cm\ s^{-1}$
z	height from ocean bottom, cm
z_1	heights of circle points, cm
z_2	heights of cross and dot points, cm

Δz_1 distance between two vertically adjacent circle points, cm
 Δz_2 distance between two vertically adjacent cross or dot points
 ρ density, g cm⁻³
 ρ_0 a constant density, 1 g cm⁻³
 ρ_r a reference density, varying only in z-direction, g cm⁻³

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Discussions with Dr. R. V. Madala on the SEVP solver and the skillful typing of Mrs. Doris Beechum and Mrs. Judy Staudinger are greatly appreciated.

REFERENCE

Madala, R. V., 1978: An Efficient Direct Solver for Separable and Non-Separable Elliptic Equations. Month Weather Review, 106, 1735-1741.

APPENDIX A — FORTRAN CODE FOR THE NON-HYDROSTATIC MODEL

A listing of FORTRAN code of the ocean model. The major functions of the main program and subroutines are as follows:

OCEAN	main program, calls all subroutines, manages job flow, controls input/output.
INIT	sets up independent variables, defines constants
START	defines initial conditions
{ PUTOUT	gets various fields ready for output
{ MAP	prints
ADVECT	computes all inviscous terms, except for the pressure gradient forces
DIFF	computes horizontal and vertical diffusions
PRESS	solves the pressure diagnostic equations and computes the pressure gradient forces, appears only in the non-hydrostatic version
{ MATINV	} Used in SEVP method
{ BSM1	
{ BSM2	
{ BSM3	
FRWRD	matches forward
BOUNDV	sets outer boundary conditions for momentum
CHECK	checks if the time step is linearly stable.

APPENDIX B — FORTRAN CODE FOR THE HYDROSTATIC MODEL

The hydrostatic version of the model can be obtained by simplifying the non-hydrostatic version. In the hydrostatic version, the equation of motion in z -direction (1-5) is reduced to the hydrostatic equation

$$-\frac{1}{\rho_0} \frac{\partial p}{\partial z} = b \quad (B-1)$$

Instead of solving the elliptic equation (4-5), the pressure p is thus obtainable by vertically integrating (B-1). The vertical velocity w can also be computed by vertically integrating the continuity equation (1-7).

The FD forms of (B-1) and (1-7) are, respectively,

$$p_{ij} = p_{ij-1} - 0.5 \rho_0 (\Delta z_r)_j (B_{ij}^t + B_{ij-1}^t) \quad (B-2)$$

$$w_{ij} = w_{ij} + \frac{\left[(r_1)_{i+1} u_{i+1,j-1}^t - (r_1)_i u_{ij-1}^t \right] (\Delta z_1)_j}{0.5 (\Delta r_1)_i \left[(r_1)_{i+1} + (r_1)_i \right]} \quad (B-3)$$

<<SPLIT OCEANO,SOLRC0,PRINT,SEG

```

1*      PROGRAM OCEAN                                0001000
2*      PARAMETER M=21,N=21                          0002000
3*      PARAMETER M1=M-1,P2=M-2,N1=N-1,N2=N-2       0003000
4*      PARAMETER NPM=2*M*N1+M1*N+M1*N1            0004000
5*      DIMENSION DATA1(NC),DATA2(NC),DATA3(NC)     0005000
6*      COMMON/ONE/VR1(M,N1),VT1(M,N1),VZ1(M1,N),B1(M1,N1),VR2(M,N1), 0006000
7*      1 VT2(M,N1),VZ2(M1,N),B2(M1,N1),VR3(M,N1),VT3(M,N1), 0007000
8*      2 VZ3(M1,N),B3(M1,N1),P(M1,N1)              0008000
9*      EQUIVALENCE (DATA1,VR1),(DATA2,VR2),(DATA3,VR3) 0009000
10*     DATA DATA1/ND*0.,/DATA2/ND*0.,/DATA3/ND*0./ 0010000
11*     COMMON/TMP/R1(M),R2(M1),DR1(M1),DR2(M),Z1(N),Z2(N1),DZ1(N1),DZ2(N) 0011000
12*     COMMON/TMP/RMR,MHPR(N1),BV2(N),ALPHA,BNDA,BNOB,CORI,G,HK(N),ZK(N) 0012000
13*     COMMON/PCO/DELT,XTIME,ITIME,ISTEP,ISMO,ITAPE,TBV 0013000
14*     CALL INDDMP                                0014000
15*     100 FORMAT(I4)                             0015000
16*     READ(5,100)ITIME                            0016000
17*     READ(5,100)ITER                              0017000
18*     READ(5,100)IRUT                              0018000
19*     READ(5,100)ISMO                              0019000
20*     ISTEP=0                                       0020000
21*     READ(5,100)ITAPE                             0021000
22*     CALL INIT                                    0022000
23*     IF(ITIME.EQ.0)GO TO 10                       0023000
24* C                                                0024000
25* C          CONTINUED INTEGRATION FROM A HISTORY TAPE 0025000
26* C                                                0026000
27* C     READ(1)ITIME,DATA1,DATA2,P                 0027000
28* C     GO TO 20                                    0028000
29* 10 CALL START                                    0029000
30* 20 XTIME=ITIME+3600.                             0030000
31* C                                                0031000
32* C          PRINT OUT INITIAL FIELDS                0032000
33* C                                                0033000
34* C     CALL PUTOUT                                0034000
35* C     IF(ITER.EQ.0)STOP                          0035000
36* C     OR 90 ISTEP=1,ITER                        0036000
37* C                                                0037000
38* C          COMPUTE ALL INVISCID TERMS                0038000
39* C                                                0039000
40* C     CALL ADVECT                                0040000
41* C                                                0041000
42* C          COMPUTE VISCOUS TERMS                    0042000
43* C                                                0043000
44* C     CALL DIFF                                  0044000
45* C                                                0045000
46* C          AND ADD PRESSURE GRADIENT FORCES TO TENDENCIES 0046000
47* C          DIAGNOSE (RECOVER) THE PRESSURE FIELD    0047000
48* C                                                0048000
49* C     CALL PRESS                                0049000
50* C                                                0050000
51* C          MARCHING IN TIME                          0051000
52* C          FIRST TIME STEP IS FORWARD IF START IS CALLED 0052000
53* C                                                0053000
54* C     IF(ISTEP.EQ.1.AND.ITIME.EQ.0)DELT=0.5*DELT 0054000
55* C     CALL FMMWD                                  0055000
56* C     IF(ISTEP.EQ.1.AND.ITIME.EQ.0)DELT=2.*DELT 0056000
57* C                                                0057000
58* C          DEFINE BOUNDARY VALUES FOR VELOCITY      0058000
59* C                                                0059000
60* C     CALL BRUNDV                                0060000
61* C                                                0061000
62* C          CHECK IF DELT IS STABLE                   0062000
63* C CC                                              0063000
64* C     CALL CHECK                                  0064000
65* C     XTIME=XTIME+DELT                            0065000
66* C     ITIME=XTIME/3600.                           0066000
67* C                                                0067000
68* C          PRINT OUT RESULTS EVERY IRUT STEPS        0068000
69* C                                                0069000
70* C     IF(MOD(ISTEP,IRUT).EQ.0)CALL PUTOUT          0070000
71* C                                                0071000
72* C          WRITE HISTORY TAPE EVERY ITAPE STEPS      0072000
73* C CC                                              0073000
74* C     IF(MOD(ISTEP,ITAPE).EQ.0)WRITE(2)ITIME,DATA1,DATA2,P 0074000
75* 90 CONTINUE                                     0075000
76* STOP                                           0076000
77* END                                           0077000

```

*** MEMBER INIT

```

1* SUBROUTINE INIT                                0001000
2* PARAMETER M=21,N=21                            0002000
3* PARAMETER M1=M+1,M2=M+2,N1=N+1,N2=N+2          0003000
4* COMMON/ONE/VR1(M,A1),VT1(M,N1),VZ1(M1,N),R1(M1,N1),VR2(M,A1), 0004000
5* VT2(M,N1),VZ2(M1,N),R2(M1,N1),VR3(M,N1),VT3(M,N1), 0005000
6* VZ3(M1,A),R3(M1,N1),P(M1,N1)                 0006000
7* COMMON/TWO/R1(M),R2(M1),DR1(M1),DR2(M),Z1(N),Z2(N1),DZ1(N1),DZ2(N) 0007000
8* COMMON/THREE/RRR(M),RRR(N1),RV2(N),ALPHA,BNDA,BNDR,CORI,G,HK(M),ZK(N) 0008000
9* COMMON/FOR/DELTA,XTIME,ITIME,ISTEP,ISMO,ITAPE,TBV 0009000
10* PARAMETER MP=M+1,MPN=1                        0010000
11* PARAMETER NPLK=2,NBLK1=NBLK=1                 0011000
12* PARAMETER MP1=MP+1,MP2=MP+2,NP1=NP+1,NP2=NP+2 0012000
13* REAL*8 RCCR,RINV,RINV1,RTILDA                 0013000
14* COMMON/EVP/RINV(MF2,MP2,NBLK),RINV1(MP2,MP2,NBLK1),RCCR(MP,3), 0014000
15* RTILDA(MP2),F(MP,NP),NSIZ2(NBLK),IS(NBLK),SLMF(NBLK), 0015000
16* IE(NBLK),F11(MP),F14(MP),F21(MP),F24(MP),AX(MP),AY(MP), 0016000
17* RB(MP,NP),CX(MP),CY(MP)                      0017000
18* C                                                0018000
19* C INITIALIZE ALL DEPENDENT VARIABLES AND CONSTANTS 0019000
20* C                                                0020000
21* C ALPHA IS THE NONDIMENSIONAL SMOOTHING COEF. 0021000
22* C FOR TIME SMOOTHING IN SUBROUTINE FWARD 0022000
23* C                                                0023000
24* C DELTA=900. 0024000
25* C ALPHA=0.10 0025000
26* C G=980. 0026000
27* C LAT=30 0027000
28* C CRR1=2.*7.2722E-5*SIN(LAT*3.14159/180.) 0028000
29* C                                                0029000
30* C DEFINE RADII AT GRID POINTS AND ALL GRID INTERVALS 0030000
31* C                                                0031000
32* C DR 10 I=1,M1 0032000
33* C DR1(I)=20.E5 0033000
34* C R1(I)=0. 0034000
35* C DR 20 I=2,M 0035000
36* C R1(I)=R1(I-1)+DR1(I-1) 0036000
37* C DR 30 I=1,M1 0037000
38* C R2(I)=0.5*(R1(I)+R1(I+1)) 0038000
39* C DR2(I)=2.*(R2(I)-R1(I)) 0039000
40* C DR2(M)=2.*(R1(M)-R2(M)) 0040000
41* C DR 40 I=2,M1 0041000
42* C DR2(I)=R2(I)-R2(I-1) 0042000
43* C DR2(M)=R2(M)-R2(M-1) 0043000
44* C MAX=MAX(MAG(DR1)) 0044000
45* C DRMAX=DR1(MAX) 0045000
46* C DRMAX=DR1(MAX) 0046000
47* C DEFINE ALL DZ'S 0047000
48* C DR 100 J=1,N 0048000
49* C Z1(J)=(J-1)*200.F2 0049000
50* C DR 110 J=1,N1 0050000
51* C DZ1(J)=Z1(J+1)-Z1(J) 0051000
52* C DZ2(1)=2.*(0.5*(Z1(1)+Z1(2))-Z1(1)) 0052000
53* C Z2(1)=0.5*DZ2(1) 0053000
54* C DR 120 J=2,N1 0054000
55* C DZ2(J)=0.5*(DZ1(J)+DZ1(J+1)) 0055000
56* C Z2(J)=Z2(J-1)+DZ2(J) 0056000
57* C DZ2(N)=2.*(Z1(N)-Z1(N-1))+0.5*DZ1(N1) 0057000
58* C MAX=MAX(MAG(DZ1)) 0058000
59* C DZMAX=DZ1(MAX) 0059000
60* C DZMAX=DZ1(MAX) 0060000
61* C DEFINE CONSTANTS FOR SEVP SOLVER 0061000
62* C AX(1)=0. 0062000
63* C CX(MP)=0. 0063000
64* C AY(1)=0. 0064000
65* C CY(MP)=0. 0065000
66* C DR 50 I=1,M1 0066000
67* C AX(I+1)=R1(I)/(0.5*(R1(I)+R1(I+1))+CR1(I)+DR1(I)) 0067000
68* C CX(I+1)=R1(I+1)/(0.5*(R1(I)+R1(I+1))+CR1(I)+DR1(I+1)) 0068000
69* C DR 60 J=1,N1 0069000
70* C AY(J+1)=R1(J)/(DZ1(J)+DZ2(J)) 0070000
71* C CY(J+1)=R1(J)/(DZ1(J)+DZ2(J+1)) 0071000
72* C DR 70 J=1,NP 0072000
73* C RB(J)=CX(I)-AX(I)-CY(J)-AY(J) 0073000
74* C NSIZE=N1+NBLK=NR(N1,2) 0074000
75* C DR 80 NP=1,NBLK1 0075000
76* C NSIZ2(NB)=NSIZE 0076000
77* C NSIZ2(NBLK)=N1+(NBLK-1)*NSIZE+NBLK1 0077000
78* C NSIZ2(NBLK)=N1+(NBLK-1)*NSIZE+NBLK1 0078000
79* C NSIZ2(NBLK)=N1+(NBLK-1)*NSIZE+NBLK1 0079000
80* C NSIZ2(NBLK)=N1+(NBLK-1)*NSIZE+NBLK1 0080000

```

*** MEMBER INIT

81* C		0000000
82* C		0001000
83* C	A AND H ARE CONSTANT USED IN SUBROUTINE BOLDV	0002000
84* C	FOR CONSTANT DIV, AND VERT. CONDITIONS	0003000
85*	RNDAB=H1(M1)/R1(M)	0004000
86*	RNCR=(R1(M1)+R1(M))*CR1(M1)/((R1(M1)+R1(M2))*R1(M)+CR1(M2))	0005000
87*	RNDAB=0.	0006000
88* C		0007000
89* C	DEFINE DENSITY RELATED CONSTANTS	0008000
90* C		0009000
91*	RH=0.1.	0010000
92*	DO 130 J=1,N	0011000
93*	130 RV2(J)=1.E-6	0012000
94*	TRV=0.	0013000
95*	DO 135 J=1,N	0014000
96*	135 TRV=MAX1(TRV,RV2(J))	0015000
97*	TRV=1./SQRT(TRV)	0016000
98* C		0017000
99* C	DEFINE HORIZONTAL AND VERTICAL DIFFUSION COEFFICIENTS	0018000
100* C		0019000
101*	CDEFH=0.002*OR(11)**2/DELT	0101000
102*	CDEFZ=0.001*OZ(11)**2/DELT	0102000
103*	DO 140 I=1,M1	0103000
104*	140 H(I)=CDEFH*(1.+5.*EXP(-FLOAT(M1-I)/7.))	0104000
105*	DO 150 J=1,N1	0105000
106*	150 ZK(J)=CDEFZ*(1.+5.*EXP(-FLOAT(J-1)/5.)*EXP(-FLOAT(N1-J)/5.))	0106000
107*	RETURN	0107000
108*	END	0108000

*** MEMBER START

```

1*      SUBROUTINE START                                0001000
2*      PARAMETER M=21,N=21                            0002000
3*      PARAMETER M1=M+1,P2=2*N+1,N1=N+1,N2=N+2        0003000
4*      COMMON/ONE/VR1(M,N),VT1(M,N),VZ1(M,N),R1(M,N),VR2(M,N),  0004000
5*      VT2(M,N),VZ2(M,N),R2(M,N),VR3(M,N),VT3(M,N),  0005000
6*      VZ3(M,N),R3(M,N),P(M,N)                        0006000
7*      COMMON/TWO/R1(M),R2(M),DR1(M),DR2(M),Z1(N),Z2(N),CZ1(N),CZ2(N) 0007000
8*      COMMON/THREE/RHM,LMR(N),RV2(N),ALPHA,BNCA,BNDR,CGR1,G,HX(N),ZK(N) 0008000
9*      PARAMETER NC=2*M+M1+M1+N+M1+N1                0009000
10*     DIMENSION DATA1(NC),DATA2(NC)                  0010000
11*     EQUIVALENCE (DATA1,VR1),(DATA2,VR2)             0011000
12* C                                                    0012000
13* C              INITIALIZE MASS FIELDS FOR A THEORETICAL RING  0013000
14* C                                                    0014000
15*      I1=1                                             0015000
16*      I2=13                                           0016000
17*      I21=I2+1                                        0017000
18*      I22=M1                                           0018000
19*      RMAG=0.0002                                     0019000
20*      DO 10 I=I1,I2                                   0020000
21*      R1(I,N1)=RMAG*CRS(FLSAT((I-I1)/P,.5,14159)*G/RM)  0021000
22*      DO 30 J=I21,I22                                 0022000
23*      R1(I,N1)=R1(I2,N1)*EXP(-FL*AT((I-I21)/4.))      0023000
24*      DO 40 J=I1,N2                                   0024000
25*      FACT=EXP(FL*AT((J-N1)/5.))                     0025000
26*      DO 40 I=1,M1                                    0026000
27*      R1(I,J)=R1(I,N1)*FACT                          0027000
28* C                                                    0028000
29* C              PRESSURE IS OBTAINED HYDROSTATICALLY FROM BUOYANCY 0029000
30* C                                                    0030000
31*      DO 50 I=1,M1                                    0031000
32*      P(I,1)=0.5*RMH+CZ2(I)*B1(I,1)                  0032000
33*      DO 60 J=2,N1                                    0033000
34*      DO 60 I=1,M1                                    0034000
35*      P(I,J)=P(I,J-1)+0.5*RMH+CZ2(J)*(B1(I,J)+B1(I,J-1)) 0035000
36* C                                                    0036000
37* C              TANGENTIAL VELOCITY IS IN GRADIENT BALANCE WITH MASS 0037000
38* C                                                    0038000
39*      DO 70 J=1,N1                                    0039000
40*      DO 70 I=2,M1                                    0040000
41*      PGF=(M(I,J)-P(I-1,J))/(RMH+CR2(I))             0041000
42*      RAD=(0.5*CRH1+M1(I))*2*R1(I)*PGF               0042000
43*      JJ=0                                             0043000
44*      II=1                                             0044000
45*      IF(MAG(LY,0.1)GT 100) GO TO 100                0045000
46*      VT1(I,J)=0.5*CRF1+R1(I)+SGFT(RAD)              0046000
47* C                                                    0047000
48* C              SET DATA2=DATA1 FOR LEAPFROG          0048000
49* C                                                    0049000
50*      DO 90 I=1,NC                                    0050000
51*      DATA2(I)=DATA1(I)                              0051000
52*      CALL HROUNDV                                     0052000
53*      DO 90 I=1,NC                                    0053000
54*      DATA1(I)=DATA2(I)                              0054000
55*      RETURN                                           0055000
56*      100 PRINT 110,I,J,JJ,PGF,RAD                   0056000
57*      110 FORMAT(' RADICAL IN SUBROUTINE START IS NEGATIVE AT (I,J)=',2I5, 0057000
58*      1 PGF, RAD =',1P2E12.3)                        0058000
59*      STOP                                             0059000
60*      END                                             0060000

```

*** MEMBER HOUNOV

```

1*      SIMULATING HOUNOV                                0001000
2*      PARAMETER M=21,N=21                                0002000
3*      PARAMETER M1=M-1,M2=M-2,N1=N-1,N2=N-2            0003000
4*      COMMON/ONE/VR1(M,N1),VT1(M,N1),VZ1(M,N1),R1(M1,N1),VR2(M,N1),  0004000
5*      1 VT2(M,N1),VZ2(M,N1),R2(M1,N1),VR3(M,N1),VT3(M,N1),  0005000
6*      2 VZ3(M1,N1),R3(M1,N1),P(M1,N1)                  0006000
7*      COMMON/TWO/PI(M),R2(M1),DR1(M1),DR2(M1),Z1(N),Z2(N1),DZ1(N1),DZ2(N) 0007000
8*      COMMON/THREE/HR(M),R2(N),BND1,ALPHA,BNDA,BNDB,CORI,G,H(M),ZK(N) 0008000
9*      C                                                    0009000
10*     C LATERAL BOUNDARY FOR TANGENTIAL AND RADIAL VELOCITIES 0010000
11*     C ASSUMING CONTINUOUS VORTICITY AND DIVERGENCE 0011000
12*     C                                                    0012000
13*     C DO 10 J=1,N1 0013000
14*     VR2(M,J)=RND1*VR2(M1,J)+RND2*(R1(M1)*VR2(M1,J)-R1(M2)*VR2(M2,J)) 0014000
15*     10 VT2(M,J)=RND1*VT2(M1,J)+RND2*(R1(M1)*VT2(M1,J)-R1(M2)*VT2(M2,J)) 0015000
16*     RETURN 0016000
17*     END 0017000

```

*** MEMBER DIFF

```

1*      SURROUTINE DIFF                                0001000
2* C                                           0002000
3* C      COMPLETE THE DIFFUSION TERMS                0003000
4* C                                           0004000
5*      PARAMETER M=21,N=21                            0005000
6*      PARAMETER M1=M-1,M2=M-2,N1=N-1,N2=N-2        0006000
7*      COMMON/PRF/VR1(M,N1),VT1(M,N1),VZ1(M,N1),B1(M1,N1),VR2(M,N1),  0007000
8*      VT2(M,N1),VZ2(M1,N1),B2(M1,N1),VR3(M,N1),VT3(M,N1),  0008000
9*      VZ3(M1,N1),B3(M1,N1),P(M1,N1)                0009000
10*      COMMON/TAC/RI(M),R2(M1),DR1(M1),DR2(M),Z1(N),Z2(N1),DZ1(N1),DZ2(N)  0010000
11*      COMMON/THR/RHR,RHR,BR(N1),BV2(N),ALPHA,BNDA,BNDB,CORI,G,HK(M),ZK(N)  0011000
12*      DIMENSION VR(M,N1),VT(M,N1),VZ(M1,N1),B(M1,N1)  0012000
13*      EQUIVALENCE (VR,VH1),(VT,VT1),(VZ,VZ1),(B,B1)  0013000
14* C                                           0014000
15* C      HORIZONTAL DIFFUSION OF RADIAL VELOCITY      0015000
16* C                                           0016000
17*      DO 10 J=1,N1                                  0017000
18*      DO 10 I=2,M1                                  0018000
19*      10 VR3(I,J)=VR3(I,J)+HK(I)*(((VR(I+1,J)-VR(I,J))/DR1(I)  0019000
20*      = (VR(I,J)-VR(I-1,J))/DR1(I-1))/DR2(I)-VR(I,J)/(R1(I)*R1(I))  0020000
21*      +0.5*((VR(I+1,J)-VR(I,J))/(DR1(I)*R2(I))  0021000
22*      + (VR(I,J)-VR(I-1,J))/(DR1(I-1)*R2(I-1))))  0022000
23* C                                           0023000
24* C      HORIZONTAL DIFFUSION OF TANGENTIAL VELOCITY  0024000
25* C                                           0025000
26*      DO 20 J=1,N1                                  0026000
27*      DO 20 I=2,M1                                  0027000
28*      20 VT3(I,J)=VT3(I,J)+HK(I)*(((VT(I+1,J)-VT(I,J))/DR1(I)  0028000
29*      = (VT(I,J)-VT(I-1,J))/DR1(I-1))/DR2(I)-VT(I,J)/(R1(I)*R1(I))  0029000
30*      +0.5*((VT(I+1,J)-VT(I,J))/(DR1(I)*R2(I))  0030000
31*      + (VT(I,J)-VT(I-1,J))/(DR1(I-1)*R2(I-1))))  0031000
32* C                                           0032000
33* C      HORIZONTAL DIFFUSION OF VERTICAL VELOCITY    0033000
34* C                                           0034000
35*      DO 30 J=2,N1                                  0035000
36*      DO 30 I=2,M2                                  0036000
37*      30 VZ3(I,J)=VZ3(I,J)+HK(I)*(((VZ(I+1,J)-VZ(I,J))/DR2(I+1)  0037000
38*      = (VZ(I,J)-VZ(I-1,J))/DR2(I))/DR1(I)  0038000
39*      +0.5*((VZ(I+1,J)-VZ(I,J))/(DR2(I+1)*R1(I+1))  0039000
40*      + (VZ(I,J)-VZ(I-1,J))/(DR2(I)*R1(I))))  0040000
41*      DO 40 J=2,N1                                  0041000
42*      40 VZ3(I,J)=VZ3(I,J)+HK(I)*((VZ(2,J)-VZ(1,J))/(DR2(1)*CR1(1))  0042000
43*      +0.5*(VZ(2,J)-VZ(1,J))/(DR2(2)*R1(2)))  0043000
44*      DO 50 J=2,N1                                  0044000
45*      50 VZ3(M1,J)=VZ3(M1,J)+HK(M1)*((VZ(M1,J)+VZ(M2,J))/(DR2(M1)*DR1(M1))  0045000
46*      + (VZ(M1,J)+VZ(M2,J))/(DR2(M1)*R1(M1)))  0046000
47* C                                           0047000
48* C      HORIZONTAL DIFFUSION OF B                    0048000
49* C                                           0049000
50*      DO 60 J=1,N1                                  0050000
51*      DO 60 I=2,M2                                  0051000
52*      60 B3(I,J)=B3(I,J)+HK(I)*(((B(I+1,J)-B(I,J))/DR2(I+1)  0052000
53*      = (B(I,J)-B(I-1,J))/DR2(I))/CR1(I)  0053000
54*      +0.5*((B(I+1,J)-B(I,J))/(DR2(I+1)*R1(I+1))  0054000
55*      + (B(I,J)-B(I-1,J))/(DR2(I)*R1(I))))  0055000
56*      DO 70 J=1,N1                                  0056000
57*      70 B3(I,J)=B3(I,J)+HK(I)*((B(2,J)-B(1,J))/(DR2(2)*DR1(1))  0057000
58*      +0.5*(B(2,J)-B(1,J))/(DR2(2)*R1(2)))  0058000
59*      DO 80 J=1,N1                                  0059000
60*      80 B3(M1,J)=B3(M1,J)+HK(M1)*((B(M1,J)+B(M2,J))/(DR2(M1)*DR1(M1))  0060000
61*      + (B(M1,J)+B(M2,J))/(DR2(M1)*R1(M1)))  0061000
62* C                                           0062000
63* C      VERTICAL DIFFUSION OF RADIAL VELOCITY        0063000
64* C                                           0064000
65*      DO 90 J=2,M2                                  0065000
66*      DO 90 I=2,M1                                  0066000
67*      90 VR3(I,J)=VR3(I,J)+ZK(J)*((VR(I,J+1)-VR(I,J))/DZ2(J+1)  0067000
68*      = (VR(I,J)-VR(I,J-1))/DZ2(J))/DZ1(J)  0068000
69*      DO 100 I=2,M1                                  0069000
70*      100 VR3(I,1)=VR3(I,1)+ZK(1)*((VR(I,2)-VR(I,1))/DZ2(2)+DZ1(1))  0070000
71*      DO 110 I=2,M1                                  0071000
72*      110 VR3(I,N1)=VR3(I,N1)+ZK(N1)*((VR(I,N1)+VR(I,N2))/DZ2(N1)+DZ1(N1))  0072000
73* C                                           0073000
74* C      VERTICAL DIFFUSION OF TANGENTIAL VELOCITY    0074000
75* C                                           0075000

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*** MEMBER DIFF

```

76*      CM 120 J=2,M=2                      0076000
77*      CM 120 I=2,M=1                      0077000
78*      120 VT3(I,J)=VT3(I,J)+ZK(J)*((VT(I,J+1)-VT(I,J))/DZ2(J+1)  0078000
79*          1      -(VT(I,J)-VT(I,J=1))/DZ2(J))/DZ1(J)          0079000
80*      CM 130 I=2,M=1                      0080000
81*      130 VT3(I,1)=VT3(I,1)+ZK(1)*(VT(I,2)-VT(I,1))/(DZ2(2)+DZ1(1))  0081000
82*      CM 140 I=2,M=1                      0082000
83*      140 VT3(I,M1)=VT3(I,M1)+ZK(M1)*((VT(I,M1)-VT(I,M2))/(DZ2(M1)+DZ1(M1))  0083000
84*                                          0084000
85* C                                          0085000
86* C          VERTICAL DIFFUSION OF VERTICAL VELOCITY          0086000
87* C                                          0087000
88*      CM 150 J=2,M=1                      0088000
89*      CM 150 I=1,M=1                      0089000
90*      150 VZ3(I,J)=VZ3(I,J)+ZK(J)*((VZ(I,J+1)-VZ(I,J))/DZ1(J)  0090000
91*          1      -(VZ(I,J)-VZ(I,J=1))/DZ1(J=1))/DZ2(J)          0091000
92* C                                          0092000
93* C          VERTICAL DIFFUSION OF B          0093000
94* C                                          0094000
95*      CM 160 J=2,M=2                      0095000
96*      CM 160 I=1,M=1                      0096000
97*      160 B3(I,J)=B3(I,J)+ZK(J)*((B1(I,J+1)-B1(I,J))/DZ2(J+1)  0097000
98*          1      -(B1(I,J)-B1(I,J=1))/DZ2(J))/DZ1(J)          0098000
99*      CM 170 I=1,M=1                      0099000
100*      170 B3(I,1)=B3(I,1)+ZK(1)*(B1(I,2)-B1(I,1))/(DZ2(2)+DZ1(1))  0100000
101*      CM 180 I=1,M=1                      0101000
102*      180 B3(I,M1)=B3(I,M1)+ZK(M1)*((B1(I,M1)-B1(I,M2))/(DZ2(M1)+DZ1(M1))  0102000
103*      RETURN                      0103000
104*      END                      0104000

```

*** MEMHEN FNRRO

1*	SUBROUTINE FNRRL	0001000
2*	PARAMETER M=21,N=21	0002000
3*	PARAMETER M1=M-1,P2=M-2,N1=N-1,N2=N-2	0003000
4*	PARAMETER N0=2,M=N1+P1,N=N,M1=N1	0004000
5*	COMMON/ONE/DATA1(N0),DATA2(N0),DATA3(N0),P(M1,N1)	0005000
6*	COMMON/TWO/RMP,CHCR(N1),BV2(N),ALPHA,BNDA,BNDB,CORI,G,HX(M),ZK(N)	0006000
7*	COMMON/THREE/DELTA,XTIME,ITIME,ISTEP,ISMO,ITAPE,TBV	0007000
8*		0008000
9*	REPLACE DATA3 WITH THE NEW VALUES	0009000
10*		0010000
11*	DO 10 I=1,N0	0011000
12*	10 DATA3(I)=DATA1(I)+2.*DELTA*DATA2(I)	0012000
13*		0013000
14*	TYPE SMOOTHING	0014000
15*		0015000
16*	IF (MOD(ISTEP,ISMO).NE.0) GO TO 30	0016000
17*	DO 20 I=1,N0	0017000
18*	20 DATA2(I)=DATA2(I)+(DATA1(I)+DATA3(I)-2.*DATA2(I))*ALPHA	0018000
19*	30 CONTINUE	0019000
20*		0020000
21*	FORWARD MARCHING	0021000
22*		0022000
23*	DO 40 I=1,N0	0023000
24*	40 DATA1(I)=DATA2(I)	0024000
25*	DO 50 I=1,N0	0025000
26*	50 DATA2(I)=DATA3(I)	0026000
27*		0027000
28*	ZERO OUT DATA3 FOR NEXT STEP	0028000
29*		0029000
30*	DO 60 I=1,N0	0030000
31*	60 DATA3(I)=0.	0031000
32*	RETURN	0032000
33*	END	0033000

*** MEMBEN CHECK

```

1*      SUBROUTINE CHECK                                0001000
2*      PARAMETER M=21,N=21                            0002000
3*      PARAMETER M1=1,P2M=2,N1=N=1,P2N=2            0003000
4*      COMMON/ONE/VR1(M,N1),VT1(M,N1),VZ1(M1,N),R1(M1,N1),VR2(M,N1), 0004000
5*      1      VT2(M,N1),VZ2(M1,N),R2(M1,N1),VR3(M,N1),VT3(M,N1), 0005000
6*      2      VZ3(M1,N),R3(M1,N1),P(M1,N1)           0006000
7*      COMMON/TWO/R1(M),R2(M1),DR1(M1),DR2(M),Z1(N),Z2(N1),DZ1(N1),DZ2(N) 0007000
8*      COMMON/FOR/DELT,XTIME,ITIME,ISTEP,ISHR,ITAPE,TBV 0008000
9*      DIMENSION WORK1(M),WORK2(N)                   0009000
10*     DO 10 J=1,M1                                    0010000
11*     DO 20 I=1,M                                     0011000
12*     20 WORK1(I)=DR2(I)/APAX1(1.,VR2(I,J))          0012000
13*     MIN=MIN(MAG(WORK1))+1                           0013000
14*     DT=WORK1(MIN)*0.9                               0014000
15*     DT=AMINI(DT,DELT)                              0015000
16*     10 CONTINUE                                    0016000
17*     DO 40 I=1,M1                                    0017000
18*     DO 30 J=1,N                                     0018000
19*     30 WORK2(J)=DZ2(J)/APAX1(1.,VZ2(I,J))          0019000
20*     MIN=MIN(MAG(WORK2))+1                           0020000
21*     DT=WORK2(MIN)*0.9                               0021000
22*     DT=AMINI(DT,DELT)                              0022000
23*     40 CONTINUE                                    0023000
24*     DT=AMINI(DT,TRV)                                0024000
25*     IF (DT.GE.,DELT)RETURN                          0025000
26*     DELT=0.75*DELT                                  0026000
27*     PRINT 100,DELT                                  0027000
28*     100 FORMAT(////////,'*****DELT IS CHANGED TO',IPE11.2,' S*****') 0028000
29*     RETURN                                           0029000
30*     END                                              0030000

```

*** MEMBER ZILCH

```
1*      SUBROUTINE ZILCH(A,N)
2*      DIMENSION A(N)
3*      DO 10 I=1,N
4*      10 A(I)=0.
5*      RETURN
6*      END
```

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0001000
0002000
0003000
0004000
0005000
0006000
```

*** MEMBER ADVECT

```

1A      SUBROUTINE ADVECT                                0001000
2A C
3A C      COMPLETE THE ADVECTIVE TERMS                    0002000
4A C
5A      PARAMETER M=21,N=21                                0003000
6A      PARAMETER M1=M-1,M2=M-2,N1=N-1,N2=N-2            0004000
7A      COMMON/ONE/VR1(M,N1),VT1(M,N1),VZ1(M,N1),B1(M1,N1),VR2(M,N1), 0005000
8A      VT2(M,N1),VZ2(M1,N1),B2(M1,N1),VR3(M,N1),VT3(M,N1), 0006000
9A      VZ3(M1,N1),B3(M1,N1),P(M1,N1)                   0007000
10A     COMMON/TMR/R1(M),R2(M1),DR1(M1),DR2(M),Z1(N),Z2(N1),DZ1(N1),DZ2(N) 0008000
11A     COMMON/TMR/RMR,HR(M),BV2(N),ALPHA,BNDA,BNDB,COR1,G,MK(M),ZK(N) 0009000
12A     DIMENSION VR(M,N1),VT(M,N1),VZ(M1,N1),B(M1,N1) 0010000
13A     EQUIVALENCE (VR,VR2),(VT,VT2),(VZ,VZ2),(B,B2)    0011000
14A C
15A C      HORIZONTAL ADVECTION FOR RADIAL VELOCITY      0012000
16A C
17A     DO 10 J=1,N1                                       0013000
18A     DO 10 I=2,M1                                       0014000
19A     10 VR3(I,J)=0.25*((VR(I,J)+VR(I-1,J))*(VR(I,J)-VR(I-1,J))/DR1(I-1) 0015000
20A     1      *(VR(I+1,J)+VR(I,J))*(VR(I+1,J)-VR(I,J))/DR1(I)) 0016000
21A     2      *VR3(I,J)                                   0017000
22A C
23A C      HORIZONTAL ADVECTION FOR TANGENTIAL VELOCITY  0018000
24A C
25A     DO 20 J=1,N1                                       0019000
26A     DO 20 I=2,M1                                       0020000
27A     20 VT3(I,J)=0.25*((VR(I,J)+VR(I-1,J))*(VT(I,J)-VT(I-1,J))/DR1(I-1) 0021000
28A     1      *(VR(I+1,J)+VR(I,J))*(VT(I+1,J)-VT(I,J))/DR1(I)) 0022000
29A     2      *VT3(I,J)                                   0023000
30A C
31A C      HORIZONTAL ADVECTION FOR VERTICAL VELOCITY    0024000
32A C
33A     DO 30 J=2,N1                                       0025000
34A     DO 30 I=2,M2                                       0026000
35A     30 VZ3(I,J)=0.25*((VR(I,J)+VR(I,J-1))*(VZ(I,J)-VZ(I-1,J))/DR2(I) 0027000
36A     1      *(VR(I+1,J)+VR(I+1,J-1))*(VZ(I+1,J)-VZ(I,J))/DR2(I+1)) 0028000
37A     2      *VZ3(I,J)                                   0029000
38A     DO 40 J=2,N1                                       0030000
39A     40 VZ3(I,J)=0.25*(VR(2,J)+VR(2,J-1))*(VZ(2,J)-VZ(1,J))/DR2(2) 0031000
40A     1      *VZ3(I,J)                                   0032000
41A     DO 50 J=2,N1                                       0033000
42A     50 VZ3(M1,J)=0.25*(VR(M1,J)+VR(M1,J-1))*(VZ(M1,J)-VZ(M2,J))/DR2(M1) 0034000
43A     1      *VZ3(M1,J)                                   0035000
44A C
45A C      HORIZONTAL ADVECTION FOR BUOYANCY              0036000
46A C
47A     DO 60 J=1,N1                                       0037000
48A     DO 60 I=2,M2                                       0038000
49A     60 B3(I,J)=B3(I,J)+0.5*(VR(I,J)*(B(I,J)-B(I-1,J))/DR2(I) 0039000
50A     1      *VR(I+1,J)*(B(I+1,J)-B(I,J))/DR2(I+1)) 0040000
51A     DO 70 J=1,N1                                       0041000
52A     70 B3(I,J)=B3(I,J)+0.5*VR(2,J)*(B(2,J)-B(1,J))/DR2(2) 0042000
53A     DO 80 J=1,N1                                       0043000
54A     80 B3(M1,J)=B3(M1,J)+0.5*VR(M1,J)*(B(M1,J)-B(M2,J))/DR2(M1) 0044000
55A C
56A C      VERTICAL ADVECTION FOR RADIAL VELOCITY        0045000
57A C
58A     DO 90 J=2,N2                                       0046000
59A     DO 90 I=2,M1                                       0047000
60A     90 VR3(I,J)=VR3(I,J)+0.25*((VZ(I-1,J)+VZ(I,J))*(VR(I,J)-VR(I,J-1)) 0048000
61A     1      /DZ2(J)+(VZ(I,J+1)+VZ(I-1,J+1))*(VR(I,J+1)-VR(I,J)) 0049000
62A     2      /DZ2(J+1))                                   0050000
63A     DO 95 I=2,M1                                       0051000
64A     95 VR3(I,1)=VR3(I,1)+0.25*(VZ(I,2)+VZ(I-1,2))*(VR(I,2)-VR(I,1)) 0052000
65A     1      /DZ2(2)                                       0053000
66A     DO 96 I=2,M1                                       0054000
67A     96 VR3(I,N1)=VR3(I,N1)+0.25*(VZ(I-1,N1)+VZ(I,N1))*(VR(I,N1)-VR(I,N2)) 0055000
68A     1      /DZ2(N1)                                       0056000
69A C
70A C      VERTICAL ADVECTION FOR TANGENTIAL VELOCITY    0057000
71A C

```

*** MEMBER ADVECT

```

72*      CN 100 J=2,M1
73*      CN 100 I=2,M1
74*      100 VT(I,J)=VT3(I,J)+0.25*(VZ(I-1,J)+VZ(I,J))*(VT(I,J)-VT(I,J-1))
75*      1      /DZ2(J)+VZ(I,J+1)+VZ(I-1,J+1))*(VT(I,J+1)-VT(I,J))
76*      2      /DZ2(J+1))
77*      CN 100 I=2,M1
78*      105 VT3(I,1)=VT3(I,1)+0.25*(VZ(I,2)+VZ(I-1,2))*(VT(I,2)-VT(I,1))
79*      1      /DZ2(2)
80*      CN 100 I=2,M1
81*      106 VT3(I,M1)=VT3(I,M1)+0.25*(VZ(I,M1)+VZ(I-1,M1))*(VT(I,M1)-VT(I,M2))
82*      1      /DZ2(M1)
83* C
84* C      VERTICAL ADVECTION FOR VERTICAL VELOCITY
85* C
86*      CN 140 J=2,M1
87*      CN 140 I=1,M1
88*      140 VZ(I,J)=VZ3(I,J)+0.25*(VZ(I,J-1)+VZ(I,J))*(VZ(I,J)-VZ(I,J-1))
89*      1      /DZ1(J)+VZ(I,J+1)+VZ(I,J))*(VZ(I,J+1)-VZ(I,J))
90*      2      /DZ1(J))
91* C
92* C      VERTICAL ADVECTION FOR B
93* C
94*      CN 150 J=2,M1
95*      CN 150 I=1,M1
96*      150 B3(I,J)=B3(I,J)+0.5*(VZ(I,J)*(B(I,J)-B(I,J-1))/DZ2(J)
97*      1      +VZ(I,J+1)*(B(I,J+1)-B(I,J))/DZ2(J+1))
98*      CN 160 I=1,M1
99*      160 B3(I,1)=B3(I,1)+0.5*(VZ(I,2)*(B2(I,2)-B2(I,1))/DZ2(2)
100*      1      +VZ(I,170)*(B1(I,170)-B1(I,171))/DZ2(170))
101*      170 B3(I,M1)=B3(I,M1)+0.5*(VZ(I,M1)*(B(I,M1)-B(I,M2))/DZ2(M1)
102* C
103* C      INERTIA TERMS FOR HORIZONTAL MOMENTUM
104* C
105*      CN 110 J=1,M1
106*      CN 110 I=2,M1
107*      VR3(I,J)=VR3(I,J)+VT(I,J)*(VT(I,J)/R1(I)+CORI)
108*      110 VT3(I,J)=VT3(I,J)+VR(I,J)*(VT(I,J)/R1(I)+CORI)
109* C
110* C      BLOYANCY TERM FOR VERTICAL ACCELERATION
111* C
112*      CN 120 J=2,M1
113*      CN 120 I=1,M1
114*      120 VZ3(I,J)=VZ3(I,J)+0.5*(B(I,J)+B(I,J-1))
115* C
116* C      STRATIFICATION TERM
117* C
118*      CN 130 J=1,M1
119*      CN 130 I=1,M1
120*      130 B3(I,J)=B3(I,J)+0.5*(VZ(I,J)+BV2(J)+VZ(I,J+1)+BV2(J+1))
121*      RETURN
122*      END

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*** MEMBER ADVECT ADDED TO SOURCE == 122 RECORDS

*** MEMBER PUTOUT

```

1*      SUBROUTINE PUTOUT                                0001000
2*      PARAMETER M=21,N=21                                0002000
3*      PARAMETER M1=M-1,M2=M-2,N1=N-1,N2=N-2            0003000
4*      COMMON/ONE/VR1(M,N1),VT1(M,N1),VZ1(M1,N),B1(M1,N1),VR2(M,N1),  0004000
5*      1 VT2(M,N1),VZ2(M1,N),B2(M1,N1),VR3(M,N1),VT3(M,N1),  0005000
6*      2 VZ3(M1,N),B3(M1,N1),P(M1,N1)                   0006000
7*      COMMON/TWO/R1(M),R2(M1),DR1(M1),DR2(M),Z1(N),Z2(N1),DZ1(N1),DZ2(N) 0007000
8*      COMMON/THREE/HR(N),BVR(N),ALPHA,BNDA,BNDR,CORI,G,MK(N) 0008000
9*      COMMON/FOR/DELT,XTIME,ITIME,ISTEP,ISHO,ITAPE,TBV  0009000
10* C
11* C
12* C
13*      DIMENSION IDUM(M,N)                                0010000
14*      700 FORMAT(////,' RADIAL VELOCITY (CM/S) AT T=,I6,' M') 0011000
15*      705 FORMAT(////,' TANGENTIAL VELOCITY (CM/S) AT T=,I6,' M') 0012000
16*      710 FORMAT(////,' VERTICAL VELOCITY (CM/S) AT T=,I6,' M') 0013000
17*      715 FORMAT(////,' ELEVANCY FIELD (*.001) AT T=,I6,' M') 0014000
18*      725 FORMAT(////,' PRESSURE (*10 DYNE/CM**2) AT TIME=,I6,' M') 0015000
19*      720 FORMAT(1M1,////,20X,'*****'  OUTPLT AT TIME =,I6,' M'  0016000
20*      1 FR,2,' DAY' ISTEP =,I7,' *****') 0017000
21*      DAY=XTIME/86400,+.0001 0018000
22*      PRINT 720,ITIME,DAY,ISTEP 0019000
23*      DO 10 J=1,N1 0020000
24*      DO 10 I=1,M 0021000
25*      10 IDUM(I,J)=VR2(I,J) 0022000
26*      PRINT 700,ITIME 0023000
27*      CALL MAP(IDUM,R1,Z2,M,N1) 0024000
28*      DO 20 J=1,N1 0025000
29*      DO 20 I=1,M 0026000
30*      20 IDUM(I,J)=VT2(I,J) 0027000
31*      PRINT 705,ITIME 0028000
32*      CALL MAP(IDUM,R1,Z2,M,N1) 0029000
33*      DO 30 J=1,N 0030000
34*      DO 30 I=1,M1 0031000
35*      30 IDUM(I,J)=VZ2(I,J) 0032000
36*      PRINT 710,ITIME 0033000
37*      CALL MAP(IDUM,R2,Z1,M1,N) 0034000
38*      DO 40 J=1,N1 0035000
39*      DO 40 I=1,M1 0036000
40*      40 IDUM(I,J)=B2(I,J)*1.E3 0037000
41*      PRINT 715,ITIME 0038000
42*      CALL MAP(IDUM,R2,Z2,M1,N1) 0039000
43*      DO 50 J=1,N1 0040000
44*      DO 50 I=1,M1 0041000
45*      50 IDUM(I,J)=P(I,J)*1.E=1 0042000
46*      PRINT 725,ITIME 0043000
47*      CALL MAP(IDUM,R2,Z2,M1,N1) 0044000
48*      RETURN 0045000
49*      END 0046000

```

*** MENUEH MAP

1*	SUBROUTINE MAP(A,M,Z,MH,NN)	0001000
2*	PARAMETER MB21,NB21	0002000
3*	DIMENSION R(MH),Z(NN)	0003000
4*	INTEGER A (M,N),IR(M),IZ(N)	0004000
5*	70 FORMAT(1HS,7X,2515)	0005000
6*	80 FORMAT(1HS,14,3X,2515)	0006000
7*	MP=MIN0(25,MH)	0007000
8*	DO 10 IR=1,MP	0008000
9*	10 IR(I)=R(I)+1,E=5+I,1	0009000
10*	DO 20 JJ=1,NN	0010000
11*	20 IZ(J)=Z(J)+1,E=C+0,1	0011000
12*	PRINT 70	0012000
13*	PRINT 70,(IR(I),I=1,MP)	0013000
14*	PRINT 70	0014000
15*	DO 30 JJ=1,NN	0015000
16*	JJ=NN+1-JJ	0016000
17*	30 PRINT 80,IZ(JJ),(A(I,J),I=1,MP)	0017000
18*	RETURN	0018000
19*	END	0019000

*** PENNEN PRESS

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1*      SUBROUTINE PRESS                                0001000
2* C
3* C      THIS SUBROUTINE SETS UP FORCING FUNCTIONS AND BOUNDARY 0002000
4* C      CONDITIONS FOR THE PRESSURE DIAGNOSTIC EQUATIONS FOR 0003000
5* C
6* C      PARAMETER M=21,N=21                                0005000
7* C      PARAMETER M1=1,M2=2,N1=1,N2=2                     0006000
8* C      PARAMETER NBLK=2,NBLK1=NBLK=1                     0007000
9* C      REAL*8 RCND,RINV,RINV1,HTILDA,DUMMY1              0008000
10* C      COMMON/FILE/VR1(M,N1),VT1(M,N1),VZ1(M1,N),R1(M1,N1),VR2(V,N1), 0010000
11* C      1 VT2(M,N1),VZ2(M1,N),R2(M1,N1),VR3(M,N1),VT3(M,N1), 0011000
12* C      2 VZ3(M1,N),R3(M1,N1),P(M1,N1)                   0012000
13* C      COMMON/TM/R1(M),R2(M1),CR1(M1),DP2(M),Z1(N),Z2(N1),CZ1(M1),DZ2(N) 0013000
14* C      COMMON/TM/R1(M),R2(M1),CR1(M1),DP2(M),Z1(N),Z2(N1),CZ1(M1),DZ2(N) 0014000
15* C
16* C      MP=NP IS THE SIZE OF X AND F                      0015000
17* C      NP=1+2,NP=1+NBLK+1                                0016000
18* C
19* C      PARAMETER MP=1,NP=1                                0017000
20* C      PARAMETER MP1=1,MP2=NP=2,NP1=NP=1,MP2=NP=2       0018000
21* C      COMMON/EVP/RINV(MP2,MP2,NBLK),RINV1(MP2,MP2,NBLK),RCND(MP,3), 0019000
22* C      1 HTILDA(MP2),F(MP,NP),NBSIZE(NBLK),IS(NBLK),SUMF(NBLK), 0020000
23* C      2 IE(NBLK),F11(MP),FIN(MP),F21(NP),F2M(NP),AX(MP),AY(NP), 0021000
24* C      3 RB(MP,NP),CX(MP),CY(MP)                        0022000
25* C      DIMENSION DUMMY1(MP2,MP2),X(MP,NP)               0023000
26* C      EQUIVALENCE(DUMMY1,RINV1(1,1,NBLK))              0024000
27* C      PARAMETER MP=NP=MP=MP                             0025000
28* C      DATA DUMMY1/MP*0.,/X/MP*0.,/                    0026000
29* C      DATA NCALL/0/                                     0027000
30* C      NBSIZE REPRESENTS NUMBER OF INTERIOR GRID POINTS IN EACH BLOCK IN X-DIR 0028000
31* C      N2 REPRESENTS NUMBER OF INTERIOR GRID POINTS IN Y-DIRECTION 0029000
32* C      NBLK REPRESENTS NUMBER OF BLOCKS IN X-DIRECTION 0030000
33* C      THE VARIABLES A11,A1N,A21,A2M TAKES THE VALUE 0 FOR DIRICHLET B.C. 0031000
34* C      AND 1 FOR NEUMANN B.C. AT THEIR RESPECTIVE BOUNDARIES ALL CORRESPOND 0032000
35* C      J=1 A1N TO J=2N A21 TO I=1 A2M TO I=M 0033000
36* C      BOUNDARY CONDITIONS ARE 0034000
37* C      X(I,1)=(1-A11)*X(I,1)+A11*(X(I,2)-F11(I)) 0035000
38* C      X(I,NP)=(1-A1N)*X(I,NP)+A1N*(X(I,NP-1)+FIN(I)) 0036000
39* C      X(1,J)=(1-A21)*X(1,J)+A21*(X(2,J)-F21(J)) 0037000
40* C      X(MP,J)=(1-A2M)*X(MP,J)+A2M*(X(MP-1,J)+F2M(J)) 0038000
41* C      NCALL=NCALL+1 0039000
42* C
43* C      DEFINE THE FORCING FUNCTION OF THE ELLIPTIC EQUATION 0040000
44* C
45* C      DO 10 J=1,MP2 0041000
46* C      DO 10 I=1,MP2 0042000
47* C      10 F(I+1,J+1)=(CX(I+1)*OR2(I+1)+VR3(I+1,J)+VZ3(I,J+1)/DZ1(J) 0043000
48* C      1 -AX(I+1)*CR2(I)+VR3(I,J)+VZ3(I,J)/DZ1(J))+RM 0044000
49* C
50* C      SET UP AN INITIAL GUESS 0045000
51* C

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*** MEMHEN PRESS

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92*      IF(NCALL,GT,1)GO TO 30      0052000
93*      DO 20 J=1,NP2              0053000
94*      DO 20 I=1,NP2              0054000
95*      20 X(I+1,J+1)=P(I,J)        0055000
96*      30 CONTINUE                 0056000
97*      CALL ZILCH(F11,MP)          0057000
98*      CALL ZILCH(F1N,MP)          0058000
99*      CALL ZILCH(F21,MP)          0059000
100* C                                0060000
101* C                                0061000
102* C      DEFINE THE FORCING AT BOUNDARY SO THAT THERE 0062000
103* C      IS GRADIENT BALANCE AT OUTER BOUNDARY      0063000
104* C                                0064000
105*      DO 605 J=2,MP1              0065000
106*      F2M(J)=RHM*DR2(M)+VT2(M,J=1)*(VT2(M,J=1)/R1(M)+CGR1) 0066000
107*      605 CONTINUE                 0067000
108*      A11=1                        0068000
109*      A21=1                        0069000
110*      A2M=1                        0070000
111*      DO 101 J=2,MP1              0071000
112*      MR(2,J)=MR(2,J)+AX(2)*A21    0072000
113*      F(2,J)=F(2,J)+AX(2)*F21(J)+A21 0073000
114*      X(1,J)=X(1,0+A21)*X(1,J)    0074000
115*      MR(MP=1,J)=MR(MP=1,J)+CX(MP=1)*A2M 0075000
116*      F(MP=1,J)=F(MP=1,J)+CX(MP=1)*F2M(J)+A2M 0076000
117*      X(MP,J)=X(1,0+A2M)*X(MP,J)  0077000
118*      101 CONTINUE                 0078000
119*      DO 102 I=2,MP1              0079000
120*      MR(I,2)=MR(I,2)+AY(2)*A11    0080000
121*      F(I,2)=F(I,2)+AY(2)*F11(I)+A11 0081000
122*      X(I,1)=X(1,0+A11)*X(I,1)    0082000
123*      MR(I,MP=1)=MR(I,MP=1)+CY(MP=1)*A1N 0083000
124*      F(I,MP=1)=F(I,MP=1)+CY(MP=1)*F1N(I)+A1N 0084000
125*      X(I,MP)=X(1,0+A11)*X(I,MP)  0085000
126*      102 CONTINUE                 0086000
127*      IF(NCALL,EQ,1)CALL BSM1      0087000
128*      EMDRHS1,E=3                  0088000
129*      CALL BSM2(X,EMDRHS,A11,A1N,A21,A2M) 0089000
130* C                                0090000
131* C                                0091000
132* C      DEFINE THE DIAGNOSED PRESSURE                0092000
133* C                                0093000
134*      DO 110 J=1,M1                0094000
135*      DO 110 I=1,M1                0095000
136*      110 P(I,J)=X(I+1,J+1)        0096000
137*      115 CONTINUE                 0097000
138* C                                0098000
139* C                                0099000
140* C      AID PRESSURE GRADIENT FORCES TO VR3 AND VZ3  0100000
141* C                                0100000
142*      DO 120 J=1,M1                0101000
143*      DO 120 I=2,M1                0102000
144*      120 VR3(I,J)=VR3(I,J)+(P(I,J)-P(I=1,J))/(RHS*DR2(I)) 0103000
145*      DO 130 J=2,M1                0104000
146*      DO 130 I=1,M1                0105000
147*      130 VZ3(I,J)=VZ3(I,J)+(P(I,J)-P(I,J=1))/(RHS*DR2(J)) 0106000
148*      RETURN                        0107000
149*      END                          0107000

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*** BEGIN HSM1

```

1*      SIGNATURE HSM1                                0001000
2*      PARAMETER MP21,MP21                            0002000
3*      PARAMETER M1=1,MP2=2,N1=1,MP2=2              0003000
4*      PARAMETER MP=1,MP2=2,NP=1,MP2=2              0004000
5*      PARAMETER N1=1,NBLK=1,NBLK=1                  0005000
6*      REAL=RCOR,RINV,RINV1,RTILDA,DUMMY1            0006000
7*      COMMON/TMP/R1(M),R2(M1),DR1(M1),DP2(M),Z1(N),Z2(N1),DZ1(N1),DZ2(N) 0007000
8*      COMMON/VP/RINV(MP2,MP2,NBLK),RINV1(MP2,MP2,NBLK),RCOR(MP,3), 0008000
9*      COMMON/VP/RINV(MP2,MP2,NBLK),RINV1(MP2,MP2,NBLK),RCOR(MP,3), 0009000
10*      1 RTILDA(MP2),F(MP,MP),NBSIZ2(NBLK),IS(NBLK),SLMF(NBLK), 0010000
11*      2 IE(NBLK),F11(MP),F14(MP),F21(MP),F24(MP),AX(MP),AY(MP), 0011000
12*      3 RB(MP,MP),CX(MP),CY(MP)                     0012000
13*      DIMENS(M,DUMMY1(MP2,MP2))                     0013000
14*      EQUIVALENCE (DUMMY1,RINV(1,1,NBLK))           0014000
15*      IE(1)=NBSIZ2(1)+2                             0015000
16*      DO 90 NR=2,NBLK                                0016000
17*      IE(NR)=IE(NR-1)+NBSIZ2(NR)+1                  0017000
18*      90 CONTINUE                                    0018000
19*      DO 95 NR=1,NBLK                                0019000
20*      IS(NR+1)=IE(NR)+1                              0020000
21*      95 CONTINUE                                    0021000
22*      IS(1)=1                                          0022000
23*      DO 115 I=1,MP2                                  0023000
24*      DO 110 J=1,3                                    0024000
25*      DO 110 I=1,MP                                  0025000
26*      HCOR(I,J)=0.0                                   0026000
27*      110 CONTINUE                                    0027000
28*      HCOR(I+1,2)=1.0                                 0028000
29*      NR=IE(1)+1                                       0029000
30*      DO 130 J=2,NRS                                   0030000
31*      DO 135 I=2,MP1                                  0031000
32*      HCOR(I,3)=(-AX(I)+RCOR(I=1,2)+AY(J)+RCOR(I,1)+RB(I,J)). 0032000
33*      HCOR(I,2)=CX(I)+RCOR(I+1,2))/CY(J)             0033000
34*      135 CONTINUE                                    0034000
35*      DO 140 I=1,MP                                   0035000
36*      HCOR(I,1)=RCOR(I,2)                             0036000
37*      HCOR(I,2)=RCOR(I,3)                             0037000
38*      140 CONTINUE                                    0038000
39*      130 CONTINUE                                    0039000
40*      DO 145 I=1,MP2                                  0040000
41*      RINV(I,1,1)=RCOR(I+1,1)                       0041000
42*      DUMMY1(I,1)=RCOR(I+1,2)                       0042000
43*      145 CONTINUE                                    0043000
44*      115 CONTINUE                                    0044000
45*      CALL MATINV(DUMMY1)                             0045000
46*      DO 160 I=1,MP2                                  0046000
47*      DO 160 I=1,MP2                                  0047000
48*      RINV1(I,J,1)=0.0                                 0048000
49*      DO 161 K=1,MP2                                  0049000
50*      RINV1(I,J,1)=RINV1(I,J,1)+DUMMY1(I,K)+RINV(K,J,1) 0050000
51*      161 CONTINUE                                    0051000
52*      160 CONTINUE                                    0052000
53*      DO 170 I=1,MP2                                  0053000
54*      DO 170 J=1,MP2                                  0054000
55*      RINV(I,J,1)=DUMMY1(I,J)                       0055000
56*      170 CONTINUE                                    0056000
57*      DO 205 NR=2,NBLK                                0057000
58*      DO 215 I=1,MP2                                  0058000
59*      DO 210 J=1,3                                    0059000
60*      DO 210 I=1,MP                                  0060000
61*      HCOR(I,J)=0.0                                   0061000
62*      210 CONTINUE                                    0062000
63*      DO 220 I=1,MP2                                  0063000
64*      HCOR(I+1,1)=RINV1(I,1,NR+1)                   0064000
65*      220 CONTINUE                                    0065000
66*      HCOR(I+1,2)=1.0                                 0066000
67*      IE1=IE(NR)+1                                    0067000
68*      IE2=IE(NR)+1                                    0068000
69*      IF(NR+1,NBLK) GO TO 232                        0069000
70*      IE2=IE2+1                                        0070000
71*      232 CONTINUE                                    0071000
72*      DO 230 J=IE1,IE2                                  0072000
73*      DO 235 I=2,MP1                                  0073000
74*      HCOR(I,3)=(-AX(I)+RCOR(I=1,2)+AY(J)+RCOR(I,1)+RB(I,J)). 0074000
75*      HCOR(I,2)=CX(I)+RCOR(I+1,2))/CY(J)             0075000
76*      235 CONTINUE                                    0076000
77*      DO 240 I=1,MP                                   0077000

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*** MEMMEM HSM1

78*		RCHM(I,1)=RCOR(I,2)	0077000
79*		RCHM(I,2)=RCOR(I,3)	0078000
80*	240	CONTINUE	0079000
81*	241	CONTINUE	0080000
82*	230	CONTINUE	0081000
83*		IF(NH.EQ.NHLK) GO TO 246	0082000
84*		DO 245 I=1,MP2	0083000
85*		RINV(I,1,NR)=RCOR(I+1,1)	0084000
86*	245	CONTINUE	0085000
87*		DO 247 I=1,MP2	0086000
88*		DUMMY1(I,1)=RCOR(I+1,2)	0087000
89*	247	CONTINUE	0088000
90*		GO TO 249	0089000
91*	246	CONTINUE	0090000
92*		DO 248 I=2,MP1	0091000
93*		DUMMY1(I,1)=MAX(I)=RCOR(I=1,2)+AY(NP=1)*RCOR(I,1)+	0092000
94*		IHH(I,MP=1)*RCOR(I,2)+CX(I)*RCOR(I+1,2)	0093000
95*	248	CONTINUE	0094000
96*	249	CONTINUE	0095000
97*	215	CONTINUE	0096000
98*		CALL MATINV(DUMMY1)	0097000
99*		IF(NH.EQ.NHLK) GO TO 275	0098000
100*		DO 260 J=1,MP2	0099000
101*		DO 261 I=1,MP2	0100000
102*		RINV(I,J,NR)=JJC	0101000
103*		DO 261 I=1,MP2	0102000
104*		RINV(I,J,NR)=RINV(I,J,NR)+DUMMY1(I,N)*RINV(N,J,NR)	0103000
105*	261	CONTINUE	0104000
106*	260	CONTINUE	0105000
107*		DO 270 J=1,MP2	0106000
108*		DO 270 I=1,MP2	0107000
109*		RINV(I,J,NR)=DUMMY1(I,J)	0108000
110*	270	CONTINUE	0109000
111*	275	CONTINUE	0110000
112*	205	CONTINUE	0111000
113*		RETURN	0112000
114*		END	0113000
			0114000

*** MEMBER MATINV

1*	SUBROUTINE MATINV(B)	0001000
2*	PARAMETER MP=21	0002000
3*	PARAMETER MP=4	0003000
4*	REAL*8 R(MP,MP)	0004000
5*	REAL*8 R1(MP),R2(MP)	0005000
6*	MP=MP+1	0006000
7*	DO 110 I=1,MP	0007000
8*	R1(I)=1./R(I,I)	0008000
9*	R(I,I)=0	0009000
10*	DO 112 J=1,MP	0010000
11*	R(I,J)=R(I,J)*R1(I)	0011000
12*	112 CONTINUE	0012000
13*	I=I+1	0013000
14*	DO 120 I=1,MP	0014000
15*	R1(I)=R(I,I)	0015000
16*	120 CONTINUE	0016000
17*	DO 125 I=1,MP	0017000
18*	R(I,I)=0	0018000
19*	125 CONTINUE	0019000
20*	DO 127 J=1,MP	0020000
21*	R2(J)=R(I,J)	0021000
22*	127 CONTINUE	0022000
23*	DO 135 I=1,MP	0023000
24*	DO 135 J=1,MP	0024000
25*	R(I,J)=R(I,I)*R2(J)	0025000
26*	135 CONTINUE	0026000
27*	110 CONTINUE	0027000
28*	R1(I)=1./R(I,I)	0028000
29*	R(MP,MP)=0	0029000
30*	DO 140 J=1,MP	0030000
31*	R(MP,J)=R(MP,J)*R1(I)	0031000
32*	140 CONTINUE	0032000
33*	DO 150 I=2,MP	0033000
34*	DO 155 I=1,I	0034000
35*	R1(I)=R(I,I)	0035000
36*	155 CONTINUE	0036000
37*	I=I+1	0037000
38*	DO 156 I=2,I	0038000
39*	R(I,I)=0	0039000
40*	156 CONTINUE	0040000
41*	DO 157 J=1,MP	0041000
42*	R2(J)=R(I,J)	0042000
43*	157 CONTINUE	0043000
44*	I=I+1	0044000
45*	DO 160 I=2,I	0045000
46*	DO 160 J=1,MP	0046000
47*	R(I,J)=R(I,J)*R1(I)	0047000
48*	160 CONTINUE	0048000
49*	150 CONTINUE	0049000
50*	RETURN	0050000
51*	END	0051000

*** MEMOEN HSM2

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1*      SLEMTITINF HSM2(X,FHWRP,A11,A1N,A21,A2M)      0001000
2*      PARAMETER M=21,N=21      0002000
3*      PARAMETER NBLK=2,NBLK1=NBLK-1      0003000
4*      PARAMETER MP=1,NP=N+1      0004000
5*      PARAMETER MP1=MP-1,MP2=MP-2,NP1=NP-1,NP2=NP-2      0005000
6*      REAL*8 RCOR,RINV,RINV1,RTILDA      0006000
7*      COMMON/EVP/RTIV(MP2,MP2,NBLK),RINV1(MP2,MP2,NBLK1),RCOR(MP,3),      0007000
8*      1      RTILDA(MP2),F(MP,NP),NSIZ2(NBLK),IS(NPLK),SUMF(NBLK),      0008000
9*      2      IE(NPLK),F11(MP),F1N(MP),F21(MP),F2N(MP),AX(MP),AY(MP),      0009000
10*      3      RRMF(MP),CX(MP),CY(MP)      0010000
11*      DIMENSION X(MP,NP)      0011000
12*      DO 90 NP=1,NBLK      0012000
13*      SUMF(NP)=0.0      0013000
14*      90 CONTINUE      0014000
15*      DO 95 NP=1,NBLK      0015000
16*      DO 95 I=2,MP1      0016000
17*      SUMF(NP)=SUMF(NP)+ABS(F(I,IE(NP))-1))      0017000
18*      95 CONTINUE      0018000
19*      DO 96 NP=1,NBLK      0019000
20*      IF(SUMF(NP).GT.1.0) GO TO 96      0020000
21*      SUMF(NP)=1.0      0021000
22*      96 CONTINUE      0022000
23*      NSTART=1      0023000
24*      DO 199 I=1,5      0024000
25*      DO 200 N=NSTART,NBLK      0025000
26*      ISPL=IS(NP)+1      0026000
27*      IE=2*IE(NP)-2      0027000
28*      DO 205 J=ISPL,IE+2      0028000
29*      DO 205 I=2,MP1      0029000
30*      X(I,J+1)=(F(I,J)+X(I)+X(I+1,J)+AY(J)+X(I,J+1)-BB(I,J)+      0030000
31*      IX(I,J)+CX(I)+X(I+1,J))/CY(J)      0031000
32*      205 CONTINUE      0032000
33*      IF(NP.EQ.NBLK) GO TO 200      0033000
34*      DO 526 I=1,11      0034000
35*      J1=IE(NP)-1      0035000
36*      DO 215 I=2,MP1      0036000
37*      RTILDA(I)=X(I,J1+1)-(F(I,J1)+X(I)+X(I+1,J1)+AY(J1)+      0037000
38*      IX(I,J1+1)+RRMF(I,J1)+X(I,J1)-CX(I)+X(I+1,J1))/CY(J1)      0038000
39*      215 CONTINUE      0039000
40*      A2=0.0      0040000
41*      DO 216 I=1,MP2      0041000
42*      A2=A2+NARS(RTILDA(I))      0042000
43*      216 CONTINUE      0043000
44*      A3=A2/SUMF(NP)      0044000
45*      IF(A3.LE.0.1) GO TO 230      0045000
46*      DO 217 I=1,3      0046000
47*      DO 217 I=1,MP      0047000
48*      RRMF(I,J)=0.0      0048000
49*      217 CONTINUE      0049000
50*      DO 223 J=1,MP2      0050000
51*      RCOR(J+1,2)=0.0      0051000
52*      DO 223 J=1,MP2      0052000
53*      RCOR(J+1,2)=RCOR(J+1,2)+RTILDA(J)+RINV(J1,J,NB)      0053000
54*      223 CONTINUE      0054000
55*      IF(NB.EQ.1) GO TO 251      0055000
56*      DO 225 J=2,MP1      0056000
57*      RCOR(J,1)=0.0      0057000
58*      DO 225 K=2,MP1      0058000
59*      RCOR(J,1)=RCOR(J,1)+RCOR(K,2)+RINV1(K=1,J=1,NP=1)      0059000
60*      225 CONTINUE      0060000
61*      DO 226 I=2,MP1      0061000
62*      X(I,IS(NB))=X(I,IS(NB))+RCOR(I,1)      0062000
63*      226 CONTINUE      0063000
64*      251 CONTINUE      0064000
65*      CALL HSM3(X,IS(NB),IE(NB))      0065000
66*      522 CONTINUE      0066000
67*      230 CONTINUE      0067000
68*      J1=IE(NB)-1      0068000
69*      DO 220 I=2,MP1      0069000
70*      X(I,J1+1)=(F(I,J1)+X(I)+X(I+1,J1)+AY(J1)+X(I,J1+1)-      0070000
71*      IBB(I,J1)+X(I,J1)-CX(I)+X(I+1,J1))/CY(J1)      0071000
72*      220 CONTINUE      0072000
73*      501 CONTINUE      0073000
74*      200 CONTINUE      0074000
75*      DO 300 NB=1,NBLK      0075000
76*      NP=NBLK-NB1+1      0076000
77*      ISPL=IS(NB)+1      0077000

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*** MEMBER USM2

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78*      IE=2*IE(NR)=2                      0078000
79*      J=IE(NR)                          0079000
80*      IF(NB.EQ.NBLK) GO TO 302          0080000
81*      DO 305 I=2,MP1                    0081000
82*      X(I,J+1)=(F(I,J)+AX(I)*X(I=1,J)+AY(J)*X(I,J=1)+AB(I,J)+ 0082000
83*      1X(I,J)+CX(I)*X(I+1,J))/CY(J)    0083000
84*      305 CONTINUE                      0084000
85*      302 CONTINUE                      0085000
86*      DO 352 I=1,10                     0086000
87*      IF(NB.EQ.NBLK) GO TO 317          0087000
88*      J1=IE(NR)=1                       0088000
89*      DO 315 I=2,MP1                    0089000
90*      RTILUA(I=1)*X(I,J1+1)=(F(I,J1)+AX(I)*X(I=1,J1)+AY(J1)+ 0090000
91*      1X(I,J1=1)+BB(I,J1)+X(I,J1)+CX(I)*X(I+1,J1))/CY(J1) 0091000
92*      315 CONTINUE                      0092000
93*      GO TO 318                          0093000
94*      317 CONTINUE                      0094000
95*      DO 319 I=2,MP1                    0095000
96*      RTILUA(I=1)*F(I,NP=1)=(AX(I)*X(I=1,NP=1)+AY(NP=1)*X(I,NP=2)+ 0096000
97*      1BB(I,NP=1)+X(I,NP=1)+CX(I)*X(I+1,NP=1)) 0097000
98*      319 CONTINUE                      0098000
99*      318 CONTINUE                      0099000
100*     A2=0.0                            0100000
101*     DO 316 I=1,MP2                    0101000
102*     A2=A2+DABS(RTILUA(I ))            0102000
103*     316 CONTINUE                      0103000
104*     A3=A2/SUMF(NR)                     0104000
105*     IF(A3.LE.ERROR) GO TO 300         0105000
106*     DO 320 J=1,3                      0106000
107*     DO 320 I=1,MP                      0107000
108*     RCRH(I,J)=0.0                     0108000
109*     320 CONTINUE                      0109000
110*     DO 324 J=1,MP2                    0110000
111*     RCRH(J+1,2)=0.0                   0111000
112*     DO 324 J1=1,MP2                   0112000
113*     RCRH(J+1,2)=RCRH(J+1,2)+RTILUA(J1)*RINV(J1,J,NB) 0113000
114*     324 CONTINUE                      0114000
115*     IF(NB.EQ.1) GO TO 551              0115000
116*     DO 325 J=2,MP1                    0116000
117*     RCRH(J,1)=0.0                     0117000
118*     DO 325 K=2,MP1                    0118000
119*     RCRH(J,1)=RCRH(J,1) +RCOR(K,2)*RINV1(K=1,J=1,NR=1) 0119000
120*     325 CONTINUE                      0120000
121*     DO 326 I=2,MP1                    0121000
122*     X(I,IS(NB))*X(I,IS(NB))+RCOR(I,1) 0122000
123*     326 CONTINUE                      0123000
124*     551 CONTINUE                      0124000
125*     CALL USM3(X,IS(NB),IE(NR))         0125000
126*     552 CONTINUE                      0126000
127*     300 CONTINUE                      0127000
128*     J1=IE(1)                           0128000
129*     DO 330 I=2,MP1                    0129000
130*     RTILUA(I=1)*X(I,J1+1)=(F(I,J1)+AX(I)*X(I=1,J1)+AY(J1)+ 0130000
131*     1X(I,J1=1)+BB(I,J1)+X(I,J1)+CX(I)*X(I+1,J1))/CY(J1) 0131000
132*     330 CONTINUE                      0132000
133*     A2=0.0                             0133000
134*     DO 332 I=1,MP2                    0134000
135*     A2=A2+DABS(RTILUA(I))              0135000
136*     332 CONTINUE                      0136000
137*     A3=A2/SUMF(1)                       0137000
138*     IF(A3.LE.ERROR) GO TO 201          0138000
139*     NSTART=2                            0139000
140*     199 CONTINUE                      0140000
141*     201 CONTINUE                      0141000
142*     DO 350 J=2,MP1                    0142000
143*     X(1,J)=(1.0+A21)*X(1,J)+A21*(X(2,J)+F21(J)) 0143000
144*     X(MP,J)=(1.0+A2M)*X(MP,J)+A2M*(X(MP=1,J)+F2M(J)) 0144000
145*     350 CONTINUE                      0145000
146*     DO 360 I=2,MP1                    0146000
147*     X(I,1)=(1.0+A11)*X(I,1)+A11*(X(I,2)+F11(I)) 0147000
148*     X(I,NP)=(1.0+A1M)*X(I,NP)+A1M*(X(I,NP=1)+F1M(I)) 0148000
149*     360 CONTINUE                      0149000
150*     DO 371 J=2,MP1                    0150000
151*     RP(2,J)=RP(2,1)+AX(2)+A21         0151000
152*     F(2,J)=F(2,J)+AX(2)+F21(J)+A21 0152000
153*     BR(MP=1,J)=BR(MP=1,J)+CX(MP=1)+A2M 0153000

```

*** MEMBER HSM2

154*	F(NP=1,J)=F(NP=1,J)+C1(NP=1)*F2*(J)*A2*	0154000
155*	371 CONTINUE	0155000
156*	01 372 I=2,NP1	0156000
157*	0B(I,2)=0B(I,2)+AY(2)*A11	0157000
158*	F(I,2)=F(I,2)+AY(2)*F11(I)*A11	0158000
159*	0B(I,NP=1)=0B(I,NP=1)+CY(NP=1)*A1N	0159000
160*	F(I,NP=1)=F(I,NP=1)+CY(NP=1)*F1N(I)*A1N	0160000
161*	372 CONTINUE	0161000
162*	RETURN	0162000
163*	END	0163000

*** MEMBER USM3

```

1*      SUBROUTINE USM3(X,ISS,IEE)                                0001000
2*      PARAMETER M=21,N=21                                      0002000
3*      PARAMETER NBLK=2,NBLK1=NBLK-1                          0003000
4*      PARAMETER MP=M+1,NP=N+1                                  0004000
5*      PARAMETER MP1=MP-1,MP2=MP-2,NP1=NP-1,NP2=NP-2          0005000
6*      REAL*8 RCOR,RINV,FINV,RTILOA                             0006000
7*      DIMENSION X(MP,NP)                                       0007000
8*      COMMON/EVP/RINV(MP2,MP2,NBLK),RINV1(MP2,MP2,NBLK1),RCOR(MP,3), 0008000
9*      1 RTILOA(MP2),F(MP,NP),NRSIZ2(NBLK),IS(NBLK),SLMF(NBLK), 0009000
10*      2 IE(NBLK),F11(MP),FIN(MP),F21(NP),F2M(NP),AX(MP),AY(NP), 0010000
11*      3 RB(MP,NP),CX(MP),CY(NP)                                0011000
12*      DO 135 I=2,MP1                                           0012000
13*      X(I,ISS+1)=X(I,ISS+1)+RCOR(I,2)                         0013000
14*      135 CONTINUE                                             0014000
15*      ISP1=ISS+1                                               0015000
16*      IE=2+IEE-2                                               0016000
17*      DO 140 J=ISP1,IE+2                                        0017000
18*      DO 145 I=2,MP1                                           0018000
19*      RCOR(I,3)=AX(I)+RCOR(I-1,2)+AY(J)+RCOR(I,1)+RB(I,J)* 0019000
20*      145 CONTINUE                                             0020000
21*      140 CONTINUE                                             0021000
22*      DO 150 I=2,MP1                                           0022000
23*      X(I,J+1)=X(I,J+1)+RCOR(I,3)                             0023000
24*      150 CONTINUE                                             0024000
25*      RCOR(I,2)=RCOR(I,3)                                      0025000
26*      150 CONTINUE                                             0026000
27*      140 CONTINUE                                             0027000
28*      RETURN                                                    0028000
29*      END                                                        0029000

```

C48PL1T OCEAN1,SOURCE1,PRINT,SEQ

```

1*      PROGRAM OCEAN                                0001000
2*      PARAMETER M=21,N=21                          0002000
3*      PARAMETER M1=M-1,M2=M-2,N1=N-1,N2=N-2       0003000
4*      PARAMETER ND=2*M*N1+M1+N1                    0004000
5*      DIMENSION DATA1(ND),DATA2(ND),DATA3(ND)      0005000
6*      COMMON/ONE/VR1(M,N1),VT1(M,N1),B1(M1,N1),VR2(M,N1), 0006000
7*      1 VT2(M,N1),B2(M1,N1),VR3(M,N1),VT3(M,N1),    0007000
8*      2 B3(M1,N1),P(M1,N1),VZ(M1,N)                0008000
9*      EQUIVALENCE (DATA1,VR1),(DATA2,VR2),(DATA3,VR3) 0009000
10*     DATA DATA1/ND*0.0,DATA2/ND*0.0,DATA3/ND*0.0/ 0010000
11*     COMMON/TWO/R1(M),R2(M1),DR1(M1),DR2(M),Z1(N),Z2(N1),DZ1(N1),DZ2(N) 0011000
12*     COMMON/THREE/RHO,RHO(N1),BV2(N),ALPHA,BNDA,BNDB,COR1,G,HX(M),ZK(N) 0012000
13*     COMMON/FOUR/DELTA,XTIME,itime,ISTEP,ISM0,ITAPE,TBV 0013000
14*     CALL INQUIRY                                  0014000
15*     100 FORMAT(I4)                                0015000
16*     READ(5,100)itime                               0016000
17*     READ(5,100)ITER                                0017000
18*     READ(5,100)IOUT                                0018000
19*     READ(5,100)ISM0                                0019000
20*     ISTEP=0                                         0020000
21*     READ(5,100)ITAPE                                0021000
22*     CALL INIT                                       0022000
23*     IF (itime.EQ.0)GO TO 10                        0023000
24* C                                                    0024000
25* C      CONTINUED INTEGRATION FROM A HISTORY TAPE  0025000
26* C                                                    0026000
27*     READ(1)itime,DATA1,DATA2,P                    0027000
28*     GO TO 20                                       0028000
29*     10 CALL START                                  0029000
30*     20 XTIME=itime*3600.                            0030000
31* C                                                    0031000
32* C      PRINT OUT INITIAL FIELDS                    0032000
33* C                                                    0033000
34*     CALL PUTOUT                                    0034000
35*     IF (ITER.EQ.0)STOP                             0035000
36*     DO 90 ISTEP=1,ITER                             0036000
37* C                                                    0037000
38* C      COMPUTE HYDROSTATIC PRESSURE AND DIAGNOSE VERTICAL VE 0038000
39* C                                                    0039000
40*     CALL UP                                        0040000
41* C                                                    0041000
42* C      COMPUTE ALL INVISCID TERMS                    0042000
43* C                                                    0043000
44*     CALL ADVECT                                    0044000
45* C                                                    0045000
46* C      COMPUTE VISCOUS TERMS                        0046000
47* C                                                    0047000
48*     CALL DIFF                                      0048000
49* C                                                    0049000
50* C      MARCHING IN TIME                              0050000
51* C      FIRST TIME STEP IS FORWARD IF START IS CALLED 0051000
52* C                                                    0052000
53*     IF (ISTEP.EQ.1.AND.itime.EQ.0)DELTA=0.5*DELTA 0053000
54*     CALL FWARD                                      0054000
55*     IF (ISTEP.EQ.1.AND.itime.EQ.0)DELTA=2.*DELTA  0055000
56* C                                                    0056000
57* C      DEFINE BOUNDARY VALUES FOR VELOCITY          0057000
58* C                                                    0058000
59*     CALL BOUNDV                                    0059000
60* C                                                    0060000
61* C      CHECK IF DELTA IS STABLE                      0061000
62* C                                                    0062000
63*     CALL CHECK                                      0063000
64*     XTIME=XTIME+DELTA                              0064000
65*     itime=XTIME/3600.                              0065000
66* C                                                    0066000
67* C      PRINT OUT RESULTS EVERY IOUT STEPS            0067000
68* C                                                    0068000
69*     IF(MOD(ISTEP,IOUT).EQ.0)CALL PUTOUT            0069000
70* C                                                    0070000
71* C      WRITE HISTORY TAPE EVERY ITAPE STEPS          0071000
72* C                                                    0072000
73*     IF(MOD(ISTEP,ITAPE).EQ.0)WRITE(2)itime,DATA1,DATA2,P 0073000
74*     90 CONTINUE                                    0074000
75*     STOP                                           0075000
76*     END                                           0076000

```

*** MEMBER INIT

```

1*      SUBROUTINE INIT                                0001000
2*      PARAMETER M=21,N=21                            0002000
3*      PARAMETER N1=M-1,N2=M-2,N1N=N-1,N2N=N-2        0003000
4*      COMMON/ONE/VR1(M,N1),VT1(M,N1),B1(M1,N1),VR2(M,N1),  0004000
5*      1 VT2(M,N1),B2(M1,N1),VR3(M,N1),VT3(M,N1),      0005000
6*      2 B3(M1,N1),P(M1,N1),VZ(M1,N)                  0006000
7*      COMMON/TWO/R1(M),R2(M1),DR1(M1),DR2(M),Z1(N),Z2(N1),DZ1(N1),DZ2(N) 0007000
8*      COMMON/THREE/RHO,RHO1,NOR(N1),BV2(N),ALPHA,BNDA,BNDB,COR1,G,HK(M),ZK(N) 0008000
9*      COMMON/FOUR/DELT,XTIME,ITIME,ISTEP,ISMO,ITAPE,TBV  0009000
10* C                                                    0010000
11* C      INITIALIZE ALL DEPENDENT VARIABLES AND CONSTANTS  0011000
12* C                                                    0012000
13* C                                                    0013000
14* C      ALPHA IS THE NONDIMENSIONAL SMOOTHING COEF.      0014000
15* C      FOR TIME SMOOTHING IN SUBROUTINE FRWD          0015000
16* C                                                    0016000
17*      DELT=900.                                         0017000
18*      ALPHA=0.10                                       0018000
19*      G=980.                                           0019000
20*      LAT=30                                           0020000
21*      COR1=2.*7.2722E-5*SIN(LAT*3.14159/180.)        0021000
22* C                                                    0022000
23* C      DEFINE RADII AT GRID POINTS AND ALL GRID INTERVALS  0023000
24* C                                                    0024000
25*      DO 10 I=1,M1                                     0025000
26*      10 DR1(I)=20.E5                                  0026000
27*      R1(I)=0.                                         0027000
28*      DO 20 I=2,M                                     0028000
29*      20 R1(I)=R1(I-1)+DR1(I-1)                       0029000
30*      DO 30 I=1,M1                                     0030000
31*      30 R2(I)=0.5*(R1(I)+R1(I+1))                    0031000
32*      DR2(I)=2.*(R2(I)-R1(I))                         0032000
33*      DR2(M)=2.*(R1(M)-R2(M1))                        0033000
34*      DO 40 I=2,M1                                     0034000
35*      40 DR2(I)=R2(I)-R2(I-1)                          0035000
36* C      MAXR=MAX(MAG(DR1))                             0036000
37* C      DR=MAX(DR1(MAX))                                0037000
38* C                                                    0038000
39* C      DEFINE ALL DZ'S                                  0039000
40* C                                                    0040000
41*      DO 100 J=1,N                                     0041000
42*      100 Z1(J)=(J-1)*200.E2                           0042000
43*      DO 110 J=1,N1                                    0043000
44*      110 DZ1(J)=Z1(J+1)-Z1(J)                        0044000
45*      DZ2(1)=2.*(0.5*DZ1(1)-Z1(1))                   0045000
46*      Z2(1)=0.5*DZ2(1)                                0046000
47*      DO 120 J=2,N1                                    0047000
48*      DZ2(J)=0.5*(DZ1(J)+DZ1(J-1))                    0048000
49*      Z2(J)=Z2(J-1)+DZ2(J)                             0049000
50*      DZ2(N)=2.*(Z1(N)-Z1(N-1))+0.5*DZ1(N1))          0050000
51* C                                                    0051000
52* C      A AND B ARE CONSTANT USED IN SUBROUTINE BLNDV   0052000
53* C      FOR CONSTANT DIV. AND VORT. CONDITIONS          0053000
54* C                                                    0054000
55*      BNDA=M1(M1)/R1(P)                                0055000
56*      BNDB=(R1(M1)+R1(M))*DR1(M1)/((R1(M1)+R1(M2))+R1(M)+DR1(M2)) 0056000
57*      BNDB=0.                                           0057000
58* C                                                    0058000
59* C      DEFINE DENSITY RELATED CONSTANTS                0059000
60* C                                                    0060000
61*      RHO=1.                                            0061000
62*      DO 130 J=1,N                                     0062000
63*      130 BV2(J)=1.E-6                                  0063000
64*      TBV=0.                                           0064000
65*      DO 135 J=1,N                                     0065000
66*      135 TBV=MAX1(TBV,BV2(J))                         0066000
67*      TBV=1./SQRT(TBV)                                0067000
68* C                                                    0068000
69* C      DEFINE HORIZONTAL AND VERTICAL DIFFUSION COEFFICIENTS  0069000
70* C                                                    0070000
71*      CPEF=0.002*DR1(1)**2/DELT                       0071000
72*      COEFZ=0.001*DZ1(1)**2/DELT                     0072000
73*      DO 140 I=1,M1                                     0073000
74*      140 HK(I)=CPEF*(1.+5.*EXP(-FLOAT(M1-I)/7.))      0074000
75*      DO 150 J=1,N1                                    0075000
76*      150 ZK(J)=COEFZ*(1.+5.*(EXP(-FLOAT(J-1)/5.)*EXP(-FLOAT(M1-J)/5.))) 0076000
77*      RETURN                                           0077000
78*      END                                              0078000

```

*** MEMBER START

```

1*      SUBROUTINE START                                0001000
2*      PARAMETER M=21,N=21                             0002000
3*      PARAMETER M1=M-1,N1=N-1,N2=N-2                 0003000
4*      COMMON/ONE/VR1(M,N1),VT1(M,N1),R1(M1,N1),VR2(M,N1), 0004000
5*      1 VT2(M,N1),B2(M1,N1),VR3(M,N1),VT3(M,N1),      0005000
6*      2 B3(M1,N1),P(M1,N1),VZ(M1,N)                  0006000
7*      COMMON/TWO/R1(M),R2(M1),DR1(M1),DR2(M),Z1(N),Z2(N1),DZ1(N1),DZ2(N) 0007000
8*      COMMON/THREE/RHO,RHO1,RHO2(N),SV2(N),ALPHA,ENDA,BNDB,CORI,G,HK(M),ZK(N) 0008000
9*      PARAMETER N0=2*M+1+N1                           0009000
10*     DIMENSION DATA1(N0),DATA2(N0)                   0010000
11*     EQUIVALENCE (DATA1,VR1),(DATA2,VR2)              0011000
12* C                                                     0012000
13* C      INITIALIZE MASS FIELDS FOR A THEORETICAL RING  0013000
14* C                                                     0014000
15*      I1=1                                             0015000
16*      I2=13                                           0016000
17*      I2=I2+1                                         0017000
18*      I22=M1                                          0018000
19*      BPA=0.0002                                       0019000
20*      DO 10 I=I1,I2                                   0020000
21* 10 B1(I,N1)=RHO*G*COS(FL0AT(I-I1)/R.*3.14159)*G/RHO 0021000
22*      DO 30 I=I21,I22                                 0022000
23* 30 B1(I,N1)=B1(I2,N1)*EXP(-FL0AT(I-I2+1)/4.)       0023000
24*      DO 40 J=1,N2                                    0024000
25*      FACT=EXP(FL0AT(J-N1)/5.)                       0025000
26*      DO 40 I=1,M1                                    0026000
27* 40 B1(I,J)=B1(I,N1)*FACT                            0027000
28* C                                                     0028000
29* C      PRESSURE IS OBTAINED HYDROSTATICALLY FROM BUOYANCY 0029000
30* C                                                     0030000
31*      DO 50 I=1,M1                                    0031000
32* 50 P(I,1)=0.5*RHO*DZ2(1)*B1(I,1)                   0032000
33*      DO 60 J=2,N1                                    0033000
34*      DO 60 I=1,M1                                    0034000
35* 60 P(I,J)=P(I,J-1)+0.5*RHO*DZ2(J)*(B1(I,J)+B1(I,J-1)) 0035000
36* C                                                     0036000
37* C      TANGENTIAL VELOCITY IS AT GRADIENT BALANCE    0037000
38* C                                                     0038000
39*      DO 70 J=1,N1                                    0039000
40*      DO 70 I=2,M1                                    0040000
41*      PGF=(P(I,J)-P(I-1,J))/(RHO*DR2(I))             0041000
42*      RAD=(0.5*CORI*R1(I))+2*R1(I)*PGF               0042000
43*      JJ=J                                             0043000
44*      II=I                                             0044000
45*      IF(MAU,LT,0.)GO TO 100                          0045000
46* 70 VT1(I,J)=0.5*CORI*R1(I)+SQRT(RAD)                0046000
47* C                                                     0047000
48* C      SET DATA2=DATA1 FOR LEAPFROG                0048000
49* C                                                     0049000
50*      DO 80 I=1,N0                                    0050000
51* 80 DATA2(I)=DATA1(I)                                0051000
52*      CALL UNLNDV                                       0052000
53*      DO 90 I=1,N0                                    0053000
54* 90 DATA1(I)=DATA2(I)                                0054000
55*      RETURN                                           0055000
56* 100 PRINT 110,II,JJ,PGF,RAD                          0056000
57* 110 FORMAT(' RADICAL IN SUBROUTINE START IS NEGATIVE AT (I,J)=',2I5, 0057000
58* 1 PGF, RAD =',1P2E12,3)                             0058000
59*      STOP                                           0059000
60*      END                                           0060000

```

*** MEMBER UP

```

1* SUBROUTINE UP                                0001000
2* PARAMETER M=21,N=21                        0002000
3* PARAMETER M1=M-1,N1=N-1,N2=N-2            0003000
4* COMMON/ONE/VR1(M,N1),VT1(M,N1),B1(M1,N1),VR2(M,N1), 0004000
5* 1 VT2(M,N1),B2(M1,N1),VR3(M,N1),VT3(M,N1), 0005000
6* 2 B3(M1,N1),P(M1,N1),VZ(M1,N) 0006000
7* COMMON/TWO/R1(M),F2(M1),DR1(M1),DR2(M),Z1(N),Z2(N1),DZ1(M1),DZ2(N) 0007000
8* COMMON/THREE/RHO,RHOC(N1),BV2(N),ALPHA,BNDA,BNDB,CORIG,G,HK(M),ZK(N) 0008000
9* PARAMETER N1=N-1 0009000
10* DATA VZ/MIN=0./ 0010000
11* C                                           0011000
12* C PRESSURE IS OBTAINED HYDROSTATICALLY FROM B 0012000
13* C                                           0013000
14* DO 10 I=1,M1 0014000
15* 10 P(I,1)=0.5*RHOC*DZ2(I)+B2(I,1) 0015000
16* DO 20 J=2,N1 0016000
17* DO 20 I=1,M1 0017000
18* 20 P(I,J)=P(I,J-1)+0.5*RHOC*DZ2(J)*(B2(I,J)+B2(I,J-1)) 0018000
19* C                                           0019000
20* C DIAGNOSE VERTICAL VELOCITY BY CONTINUITY EQUATION 0020000
21* C                                           0021000
22* DO 30 J=2,N1 0022000
23* DO 30 I=1,M1 0023000
24* 30 VZ(I,J)=VZ(I,J-1)+DZ1(J)*(R1(I+1)+VR2(I+1,J-1)-R1(I)+VR2(I,J-1)) 0024000
25* 1 / (DR1(I)+0.5*(R1(I+1)+R1(I))) 0025000
26* RETURN 0026000
27* END 0027000

```

*** MEMBER BOUNDV

```

1*      SUBROUTINE BOUNDV                                0001000
2*      PARAMETER M=21,N=21                                0002000
3*      PARAMETER M1=M-1,M2=M-2,N1=N-1,N2=N-2            0003000
4*      COMMON/ONE/VR1(M,N1),VT1(M,N1),B1(M1,N1),VR2(M,N1), 0004000
5*      1          VT2(M,N1),B2(M1,N1),VR3(M,N1),VT3(M,N1), 0005000
6*      2          B3(M1,N1),P(M1,N1),VZ(M1,N)            0006000
7*      COMMON/TWO/R1(M),R2(M1),DR1(M1),DR2(M),Z1(N),Z2(N1),DZ1(N1),DZ2(N) 0007000
8*      COMMON/THREE/RHO,RHO(N1),BV2(N),ALPHA,BNDA,BNDB,CORIG,MU(M),ZK(N) 0008000
9*      C                                                    0009000
10*     C          LATERAL BOUNDARY FOR TANGENTIAL AND RADIAL VELOCITIES 0010000
11*     C          ASSUMING CONTINUOUS VORTICITY AND DIVERGENCE 0011000
12*     C                                                    0012000
13*     DO 10 J=1,N1                                         0013000
14*       VR2(M,J)=BNDA*VR2(M1,J)+BNDB*(R1(M1)*VR2(M1,J)-R1(M2)*VR2(M2,J)) 0014000
15*       10 VT2(M,J)=BNDA*VT2(M1,J)+BNDB*(R1(M1)*VT2(M1,J)-R1(M2)*VT2(M2,J)) 0015000
16*     RETURN                                              0016000
17*     END                                                  0017000

```

*** MEMBER DIFF

```

1*      SUBROUTINE DIFF                                0001000
2* C                                                    0002000
3* C      COMPLETE THE DIFFUSION TERMS                0003000
4* C                                                    0004000
5*      PARAMETER M=21,N=21                            0005000
6*      PARAMETER M1=M+1,M2=M+2,N1=N+1,N2=N+2          0006000
7*      COMMON/ONE/VR1(M,N1),VT1(M,N1),B1(M1,N1),VR2(M,N1), 0007000
8*      VT2(M,N1),B2(M1,N1),VR3(M,N1),VT3(M,N1),        0008000
9*      B3(M1,N1),P(M1,N1),VZ(M1,N)                   0009000
10*     COMMON/TWR/R1(M),R2(M1),DR1(M1),DR2(M),Z1(N),Z2(N1),DZ1(N1),DZ2(N) 0010000
11*     COMMON/THR/RHO,MHCR(N1),BV2(N),ALPHA,BNDA,BNOB,CORIG,MK(M),ZK(N) 0011000
12*     DIMENSION VR(M,N1),VT(M,N1),B(M1,N1)           0012000
13*     EQUIVALENCE (VR,VR1),(VT,VT1),(B,B1)           0013000
14* C                                                    0014000
15* C      HORIZONTAL DIFFUSION OF RADIAL VELOCITY      0015000
16* C                                                    0016000
17* C      DO 10 J=1,N1                                0017000
18* C      DO 10 I=2,M1                                0018000
19* 10 VR3(I,J)=VR3(I,J)+MK(I)*((VR(I+1,J)-VR(I,J))/DR1(I) 0019000
20*    1      *(VR(I,J)-VR(I-1,J))/DR1(I-1))/DR2(I)-VR(I,J)/(R1(I)*R1(I)) 0020000
21*    2      +0.5*((VR(I+1,J)-VR(I,J))/(DR1(I)*R2(I)) 0021000
22*    3      *(VR(I,J)-VR(I-1,J))/(DR1(I-1)*R2(I-1))) 0022000
23* C                                                    0023000
24* C      HORIZONTAL DIFFUSION OF TANGENTIAL VELOCITY  0024000
25* C                                                    0025000
26* C      DO 20 J=1,N1                                0026000
27* C      DO 20 I=2,M1                                0027000
28* 20 VT3(I,J)=VT3(I,J)+MK(I)*((VT(I+1,J)-VT(I,J))/DR1(I) 0028000
29*    1      *(VT(I,J)-VT(I-1,J))/DR1(I-1))/DR2(I)-VT(I,J)/(R1(I)*R1(I)) 0029000
30*    2      +0.5*((VT(I+1,J)-VT(I,J))/(DR1(I)*R2(I)) 0030000
31*    3      *(VT(I,J)-VT(I-1,J))/(DR1(I-1)*R2(I-1))) 0031000
32* C                                                    0032000
33* C      HORIZONTAL DIFFUSION OF B                    0033000
34* C                                                    0034000
35* C      DO 60 J=1,N1                                0035000
36* C      DO 60 I=2,M2                                0036000
37* 60 B3(I,J)=B3(I,J)+MK(I)*((B(I+1,J)-B(I,J))/DR2(I+1) 0037000
38*    1      *(B(I,J)-B(I-1,J))/DR2(I))/DR1(I)         0038000
39*    2      +0.5*((B(I+1,J)-B(I,J))/(DR2(I+1)*R1(I+1)) 0039000
40*    3      *(B(I,J)-B(I-1,J))/(DR2(I)*R1(I)))         0040000
41* C      DO 70 J=1,N1                                0041000
42* 70 B3(I,J)=B3(I,J)+MK(I)*((B(2,J)-B(1,J))/(DR2(2)*DR1(1)) 0042000
43*    1      +0.5*(B(2,J)-B(1,J))/(DR2(2)*R1(2)))      0043000
44* C      DO 80 J=1,N1                                0044000
45* 80 B3(M1,J)=B3(M1,J)+MK(M1)*((B(M1,J)+B(M2,J))/(DR2(M1)*DR1(M1)) 0045000
46*    1      *(B(M1,J)-B(M2,J))/(DR2(M1)*R1(M1)))      0046000
47* C                                                    0047000
48* C      VERTICAL DIFFUSION OF RADIAL VELOCITY       0048000
49* C                                                    0049000
50* C      DO 90 J=2,N2                                0050000
51* C      DO 90 I=2,M1                                0051000
52* 90 VR3(I,J)=VR3(I,J)+ZK(J)*((VR(I,J+1)-VR(I,J))/DZ2(J+1) 0052000
53*    1      *(VR(I,J)-VR(I,J-1))/DZ2(J))/DZ1(J)       0053000
54* C      DO 100 I=2,M1                               0054000
55* 100 VR3(I,1)=VR3(I,1)+ZK(1)*(VR(I,2)-VR(I,1))/(DZ2(2)+DZ1(1)) 0055000
56* C      DO 110 I=2,M1                               0056000
57* 110 VR3(I,N1)=VR3(I,N1)+ZK(N1)*((VR(I,N1)+VR(I,N2))/(DZ2(N1)+DZ1(N1)) 0057000
58* C                                                    0058000
59* C      VERTICAL DIFFUSION OF TANGENTIAL VELOCITY   0059000
60* C                                                    0060000
61* C      DO 120 J=2,N2                                0061000
62* C      DO 120 I=2,M1                                0062000
63* 120 VT3(I,J)=VT3(I,J)+ZK(J)*((VT(I,J+1)-VT(I,J))/DZ2(J+1) 0063000
64*    1      *(VT(I,J)-VT(I,J-1))/DZ2(J))/DZ1(J)       0064000
65* C      DO 130 I=2,M1                               0065000
66* 130 VT3(I,1)=VT3(I,1)+ZK(1)*(VT(I,2)-VT(I,1))/(DZ2(2)+DZ1(1)) 0066000
67* C      DO 140 I=2,M1                               0067000
68* 140 VT3(I,N1)=VT3(I,N1)+ZK(N1)*((VT(I,N1)+VT(I,N2))/(DZ2(N1)+DZ1(N1)) 0068000
69* C                                                    0069000

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*** MEMBER DIFF

70*	C		0070000
71*	C		0071000
72*	C	VERTICAL DIFFUSION OF B	0072000
73*		DO 160 J=2,N2	0073000
74*		DO 160 I=1,M1	0074000
75*	160	B3(I,J)=B3(I,J)+ZK(J)*((B1(I,J+1)-B(I,J))/DZ2(J+1)	0075000
76*	1	-(B(I,J)-B(I,J-1))/DZ2(J))/DZ1(J)	0076000
77*		DO 170 I=1,M1	0077000
78*	170	B3(I,1)=B3(I,1)+ZK(1)*(B(I,2)-B(I,1))/(DZ2(2)+DZ1(1))	0078000
79*		DO 180 I=1,M1	0079000
80*	180	B3(I,N1)=B3(I,N1)+ZK(N1)*(-B(I,N1)+B(I,N2))/(DZ2(N1)+DZ1(N1))	0080000
81*		RETURN	0081000
82*		END	0082000

*** MEMBER FRWRD

```

1*      SUBROUTINE FRWRD                                0001000
2*      PARAMETER M=21,N=21                            0002000
3*      PARAMETER M1=M-1,M2=M-2,N1=N-1,N2=N-2         0003000
4*      PARAMETER ND=2*M*N1*M1*N1                     0004000
5*      COMMON/ONE/DATA1(ND),DATA2(ND),DATA3(ND),P(M1,N1),VZ(M1,N) 0005000
6*      COMMON/THR/RHO,HCOR(N1),BV2(N),ALPHA,BNDA,BNDB,CORI,G,MH(M),ZK(N) 0006000
7*      COMMON/FGR/DELT,XTIME,ITIME,ISTEP,ISM0,ITAPE,TBV 0007000
8*      C                                                0008000
9*      C          REPLACE DATA3 WITH THE NEW VALUES 0009000
10*      C                                                0010000
11*      DO 10 I=1,ND                                    0011000
12*      10 DATA3(I)=DATA1(I)+2.*DELT*DATA2(I)         0012000
13*      C                                                0013000
14*      C          TIME SMOOTHING                      0014000
15*      C                                                0015000
16*      IF (MOD(ISTEP,ISM0).NE.0) GO TO 30             0016000
17*      DO 20 I=1,ND                                    0017000
18*      20 DATA2(I)=DATA2(I)+(DATA1(I)+DATA3(I)-2.*DATA2(I))*ALPHA 0018000
19*      30 CONTINUE                                     0019000
20*      C                                                0020000
21*      C          FORWARD MARCHING                   0021000
22*      C                                                0022000
23*      DO 40 I=1,ND                                    0023000
24*      40 DATA1(I)=DATA2(I)                          0024000
25*      DO 50 I=1,ND                                    0025000
26*      50 DATA2(I)=DATA3(I)                          0026000
27*      C                                                0027000
28*      C          ZERO OUT DATA3 FOR NEXT STEP      0028000
29*      C                                                0029000
30*      DO 60 I=1,ND                                    0030000
31*      60 DATA3(I)=0.                                0031000
32*      RETURN                                           0032000
33*      END                                              0033000

```

*** MEMBER CHECK

```

1*      SUBROUTINE CHECK                                0001000
2*      PARAMETER MB21,NB21                            0002000
3*      PARAMETER N1MB=1,N2MB=2,N1NB=1,N2NB=2          0003000
4*      COMMON/ONE/VR1(M,N1),VT1(M,N1),B1(M1,N1),VR2(M,N1), 0004000
5*      1 VT2(M,N1),B2(M1,N1),VR3(M,N1),VT3(M,N1),      0005000
6*      2 B3(M1,N1),P(M1,N1),VZ(M1,N)                 0006000
7*      COMMON/TWO/R1(M),R2(M1),DR1(M1),DR2(M1),Z1(N),Z2(N1),DZ1(N1),DZ2(N) 0007000
8*      COMMON/THREE/DELT,XTIME,ITIME,ISTEP,ISMP,ITAPE,TSV 0008000
9*      DIMENSION MARK1(M),MARK2(N)                   0009000
10*     DO 10 J=1,N1                                    0010000
11*     DO 20 I=1,M                                      0011000
12*     20 MARK1(I)=DR2(I)/APAX1(1,VR2(I,J))           0012000
13*     MIN=MIN(MAG(MARK1))+1                           0013000
14*     DT=MARK1(MIN)*0.9                               0014000
15*     DT=AMIN1(DT,DELT)                              0015000
16*     10 CONTINUE                                    0016000
17*     DT=AMIN1(DT,TSV)                                0017000
18*     IF(DT.GE,DELT)RETURN                            0018000
19*     DELT=0.75*DELT                                  0019000
20*     PRINT 100,DELT                                  0020000
21*     100 FORMAT(//////,'*****DELT IS CHANGED TO',IPE11.2,' S*****') 0021000
22*     RETURN                                           0022000
23*     END                                              0023000

```

*** MEMBER ADVECT

```

1*      SUBROUTINE ADVECT                                0001000
2* C                                          0002000
3* C      COMPLETE THE ADVECTIVE TERMS                0003000
4* C                                          0004000
5*      PARAMETER MR21,NR21                            0005000
6*      PARAMETER M1M=1,P2M=2,N1M=1,N2M=2            0006000
7*      COMMON/ONE/VR1(M,N1),VT1(M,N1),B1(M1,N1),VR2(M,N1), 0007000
8*      1      VT2(M,N1),B2(M1,N1),VR3(M,N1),VT3(M,N1), 0008000
9*      2      B3(M1,N1),P(M1,N1),VZ(M1,N1)            0009000
10*     COMMON/TWO/R1(M),R2(M1),DR1(M1),DR2(M),Z1(N),Z2(N1),DZ1(N1),DZ2(N) 0010000
11*     COMMON/THREE/RM1,RM2,RM3(N1),ALPHA,BNDA,BNDB,CORI,G,MU(M),ZK(N) 0011000
12*     DIMENSION VR(M,N1),VT(M,N1),B(M1,N1)           0012000
13*     EQUIVALENCE (VR,VR2),(VT,VT2),(B,B2)           0013000
14* C                                          0014000
15* C      HORIZONTAL ADVECTION FOR RADIAL VELOCITY    0015000
16* C                                          0016000
17*      DO 10 J=1,N1                                    0017000
18*      DO 10 I=2,M1                                    0018000
19*      10 VR3(I,J)=0.25*((VR(I,J)+VR(I-1,J))*(VR(I,J)-VR(I-1,J))/DR1(I-1) 0019000
20*      1      +(VR(I+1,J)+VR(I,J))*(VR(I+1,J)-VR(I,J))/DR1(I)) 0020000
21*      2      +VR3(I,J)                                0021000
22* C                                          0022000
23* C      HORIZONTAL ADVECTION FOR TANGENTIAL VELOCITY 0023000
24* C                                          0024000
25*      DO 20 J=1,N1                                    0025000
26*      DO 20 I=2,M1                                    0026000
27*      20 VT3(I,J)=0.25*((VT(I,J)+VT(I-1,J))*(VT(I,J)-VT(I-1,J))/DR1(I-1) 0027000
28*      1      +(VT(I+1,J)+VT(I,J))*(VT(I+1,J)-VT(I,J))/DR1(I)) 0028000
29*      2      +VT3(I,J)                                0029000
30* C                                          0030000
31* C      HORIZONTAL ADVECTION FOR BUOYANCY            0031000
32*      DO 60 J=1,N1                                    0032000
33*      DO 60 I=2,M2                                    0033000
34*      60 B3(I,J)=B3(I,J)+0.5*(VR(I,J)*(B(I,J)-B(I-1,J))/DR2(I) 0034000
35*      1      +VR(I+1,J)*(B(I+1,J)-B(I,J))/DR2(I+1)) 0035000
36*      DO 70 J=1,N1                                    0036000
37*      70 B3(I,J)=B3(I,J)+0.5*VR(2,J)*(B(2,J)-B(1,J))/DR2(2) 0037000
38*      DO 80 J=1,N1                                    0038000
39*      80 B3(M1,J)=B3(M1,J)+0.5*VR(M1,J)*(B(M1,J)-B(M2,J))/DR2(M1) 0039000
40* C                                          0040000
41* C      VERTICAL ADVECTION FOR RADIAL VELOCITY      0041000
42* C                                          0042000
43*      DO 90 J=2,N2                                    0043000
44*      DO 90 I=2,M1                                    0044000
45*      90 VR3(I,J)=VR3(I,J)+0.25*((VZ(I-1,J)+VZ(I,J))*(VR(I,J)-VR(I,J-1)) 0045000
46*      1      /DZ2(J)+(VZ(I,J+1)+VZ(I-1,J+1))*(VR(I,J+1)-VR(I,J)) 0046000
47*      2      /DZ2(J+1))                                0047000
48*      DO 95 I=2,M1                                    0048000
49*      95 VR3(I,1)=VR3(I,1)+0.25*(VZ(I,2)+VZ(I-1,2))*(VR(I,2)-VR(I,1)) 0049000
50*      1      /DZ2(2)                                    0050000
51*      DO 96 I=2,M1                                    0051000
52*      96 VR3(I,N1)=VR3(I,N1)+0.25*(VZ(I-1,N1)+VZ(I,N1))*(VR(I,N1)-VR(I,N2)) 0052000
53*      1      /DZ2(N1)                                    0053000
54* C                                          0054000
55* C      VERTICAL ADVECTION FOR TANGENTIAL VELOCITY  0055000
56* C                                          0056000
57*      DO 100 J=2,N2                                    0057000
58*      DO 100 I=2,M1                                    0058000
59*      100 VT3(I,J)=VT3(I,J)+0.25*((VZ(I-1,J)+VZ(I,J))*(VT(I,J)-VT(I,J-1)) 0059000
60*      1      /DZ2(J)+(VZ(I,J+1)+VZ(I-1,J+1))*(VT(I,J+1)-VT(I,J)) 0060000
61*      2      /DZ2(J+1))                                0061000
62*      DO 105 I=2,M1                                    0062000
63*      105 VT3(I,1)=VT3(I,1)+0.25*(VZ(I,2)+VZ(I-1,2))*(VT(I,2)-VT(I,1)) 0063000
64*      1      /DZ2(2)                                    0064000
65*      DO 106 I=2,M1                                    0065000
66*      106 VT3(I,N1)=VT3(I,N1)+0.25*(VZ(I,N1)+VZ(I-1,N1))*(VT(I,N1)-VT(I,N2)) 0066000
67*      1      /DZ2(N1)                                    0067000
68* C                                          0068000
69* C      VERTICAL ADVECTION FOR B                    0069000
70* C                                          0070000
71*      DO 150 J=2,N2                                    0071000
72*      DO 150 I=1,M1                                    0072000
73*      150 B3(I,J)=B3(I,J)+0.5*(VZ(I,J)*(B(I,J)-B(I,J-1))/DZ2(J) 0073000
74*      1      +VZ(I,J+1)*(B(I,J+1)-B(I,J))/DZ2(J+1)) 0074000
75*      DO 160 I=1,M1                                    0075000
76*      160 B3(I,1)=B3(I,1)+0.5*VZ(I,2)*(B(2,I)-B(1,I))/DZ2(2) 0076000
77*      DO 170 I=1,M1                                    0077000

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*** MEMBER ADVECT

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78* 170 B3(I,N1)=B3(I,N1)-0.5*VZ(I,N1)*(B(I,N1)-B(I,N2))/CZ2(N1)      00780000
79* C                                                                    00790000
80* C          INERTIA TERMS FOR HORIZONTAL MOMENTUM                    00800000
81* C                                                                    00810000
82*      DO 110 J=1,N1                                                    00820000
83*      DO 110 I=2,M1                                                    00830000
84*      VR3(I,J)=VR3(I,J)+VT(I,J)*(VT(I,J)/P1(I)+COR1)                00840000
85* 110 VT3(I,J)=VT3(I,J)+VR(I,J)*(VT(I,J)/P1(I)+COR1)                00850000
86* C                                                                    00860000
87* C          PRESSURE GRADIENT FORCE                                  00870000
88* C                                                                    00880000
89*      DO 120 J=1,N1                                                    00890000
90*      DO 120 I=2,M1                                                    00900000
91* 120 VR3(I,J)=VR3(I,J)-(P(I,J)-P(I-1,J))/(RHO*DR2(I))              00910000
92* C                                                                    00920000
93* C          STRATIFICATION TERM                                      00930000
94* C                                                                    00940000
95*      DO 130 J=1,N1                                                    00950000
96*      DO 130 I=1,M1                                                    00960000
97* 130 B3(I,J)=B3(I,J)+0.5*(VZ(I,J)*BV2(J)+VZ(I,J+1)*BV2(J+1))      00970000
98*      RETURN                                                            00980000
99*      END                                                                00990000

```

*** MEMBER PUTOUT

```

1* SUBROUTINE PUTOUT                                0001000
2* PARAMETER M=21,N=21                              0002000
3* PARAMETER M1=M-1,M2=M-2,N1=N-1,N2=N-2          0003000
4* COMMON/ONE/VR1(M,N1),VT1(M,N1),R1(M1,N1),VR2(M,N1), 0004000
5* 1 VT2(M,N1),B2(M1,N1),VR3(M,N1),VT3(M,N1),      0005000
6* 2 B3(M1,N1),P(M1,N1),VZ(M1,N1)                 0006000
7* COMMON/THR/R1(M),R2(M1),DR1(M1),DR2(M),Z1(N),Z2(N1),OZ1(N1),OZ2(N) 0007000
8* COMMON/THR/RMC,RMC,RMC(N1),BV2(N),ALPHA,ENOA,BNOB,COP1,G,MK(M),ZK(N) 0008000
9* COMMON/FAR/DELTA,XTIME,ITIME,ISTEP,ISHO,ITAPE,TBV 0009000
10* C                                                0010000
11* C THIS SUBROUTINE PRINT OUT FIELDS FOR A QUICK LOOK 0011000
12* C                                                0012000
13* C DIMENSION IDUM(M,N)                          0013000
14* 700 FORMAT(////,' RADIAL VELOCITY (CM/S) AT T=,I6,' M') 0014000
15* 705 FORMAT(////,' TANGENTIAL VELOCITY (CM/S) AT T=,I6,' M') 0015000
16* 710 FORMAT(////,' VERTICAL VELOCITY (CM/S) AT T=,I6,' M') 0016000
17* 715 FORMAT(////,' BUCYANCY FIELD (4.001) AT T=,I6,' M') 0017000
18* 725 FORMAT(////,' PRESSURE (*10 DYNE/CM**2) AT TIME=,I6,' M') 0018000
19* 720 FORMAT(1M1,////,'2CX,'++++++' GLTPUT AT TIME =,I6,' M 0019000
20* 1 F8.2,' DAY ISTEP =,I7,' +++++++')           0020000
21* DAY=XTIME/86400.*0.0001                        0021000
22* PRINT 720,ITIME,DAY,ISTEP                      0022000
23* DO 10 J=1,N1                                    0023000
24* DO 20 I=1,M1                                    0024000
25* 10 IDUM(I,J)=VR2(I,J)                          0025000
26* PRINT 700,ITIME                                0026000
27* CALL MAP(IDUM,R1,Z2,M,N1)                       0027000
28* DO 20 J=1,N1                                    0028000
29* DO 30 I=1,M1                                    0029000
30* 20 IDUM(I,J)=VT2(I,J)                          0030000
31* PRINT 705,ITIME                                0031000
32* CALL MAP(IDUM,R1,Z2,M,N1)                       0032000
33* DO 30 J=1,N1                                    0033000
34* DO 30 I=1,M1                                    0034000
35* 30 IDUM(I,J)=VZ(I,J)                          0035000
36* PRINT 710,ITIME                                0036000
37* CALL MAP(IDUM,R2,Z1,M1,N)                       0037000
38* DO 40 J=1,N1                                    0038000
39* DO 40 I=1,M1                                    0039000
40* 40 IDUM(I,J)=B2(I,J)*1.E3                      0040000
41* PRINT 715,ITIME                                0041000
42* CALL MAP(IDUM,R2,Z2,N1,N1)                     0042000
43* DO 50 J=1,N1                                    0043000
44* DO 50 I=1,M1                                    0044000
45* 50 IDUM(I,J)=P(I,J)*1.E-1                      0045000
46* PRINT 725,ITIME                                0046000
47* CALL MAP(IDUM,R2,Z2,M1,N1)                     0047000
48* RETURN                                           0048000
49* END                                              0049000

```

*** MENUEN MAP

1*	SUBROUTINE MAP(A,R,Z,MM,NN)	0001000
2*	PARAMETER M=21,N=21	0002000
3*	DIMENSION R(MM),Z(NN)	0003000
4*	INTEGER A (M,N),IR(M),IZ(N)	0004000
5*	70 FORMAT(1H5,7X,25I5)	0005000
6*	80 FORMAT(1H5,14,3X,25I5)	0006000
7*	MM=MIN0(25,MM)	0007000
8*	DO 10 I=1,MP	0008000
9*	10 IR(I)=R(I)+1,E=5+0.1	0009000
10*	DO 20 J=1,NN	0010000
11*	20 IZ(J)=Z(J)+1,E=2+0.1	0011000
12*	PRINT 70	0012000
13*	PRINT 70,(IR(I),I=1,MP)	0013000
14*	PRINT 70	0014000
15*	DO 30 JJ=1,NN	0015000
16*	JJ=NN+1-JJ	0016000
17*	30 PRINT 80,IZ(J),(A(I,J),I=1,MP)	0017000
18*	RETURN	0018000
19*	END	0019000

LME
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