TECHNICAL MEMORANDUM

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The forecast and analysis post processing package (revised version of Technical Memorandum 2)

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May 1982

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Europäisches Zentrum für mittelfristige Wettervorhersage
Centre européen pour les prévisions météorologiques à moyen

1. INTRODUCTION

The post-processing package provides an interface between the forecast model or the analysis system on the Cray and the archiving and dissemination systems on the Cyber. Selected fields are sent from the Cray, packed and in Cyber format. They may have been vertically interpolated, using linear or cubic spline fits, and they may have been horizontally interpolated, by fitting spherical harmonics, and then interpolating back to a regular latitude/ longitude grid.

The post-processing package may be divided into 2 parts. In the first part, a work file is generated, containing selected fields in line form. This part may either be initialised at selected time steps while a forecast model is running, or it may be a separate job, which takes as input an analysis or forecast history file. The second part of the package is a separate job, which converts the data from line to field format, and may interpolate it horizontally before packing it and converting it to Cyber format.

Section 2 describes the theory of the method used to calculate the spherical harmonic coefficients for the horizontal interpolation. Section 3 describes the forecast-called version of the first part of the post-processing package, while Section 4 describes the stand-alone version. Section 5 describes the way in which the fields are rearranged, so that they are in the most convenient order for the spherical harmonic fitting routines. Section 6 defines the format of the work file, which is the interface between the first and second part of the post-processing package. Section 7 contains a description of the second part of the package. Section 8 describes the space layout used in the second part, and the algorithms used to decide how many fields can be processed in each scan through the data. Section 9 describes the format of the 3 types of output file which may be generated by the post-processing package. Section 10 consists of tables describing the common blocks used by the post-processing package. Section 11 contains examples of the job control language used to run different parts of the package.

2. Theory of the method of calculating the spherical harmonic coefficients

The spherical harmonic coefficients are calculated, using the method described by Machenhauer and Daley (1972). Given a function which may be represented by a truncated series of spherical harmonics:-

$$\psi(\lambda,\phi) = \sum_{m=-M^*}^{M^*} \sum_{n=|m|}^{N^*} \psi_{mn} Y_{mn} (\lambda,\mu) \tag{1}$$

(where $0 \leqslant M^* \leqslant N^*$, λ = longitude, ϕ = latitude, $\mu = \sin\phi$)

then this method calculates the coefficients ψ_{mn} exactly.

$$\psi(\lambda_k,\phi_j) = \sum_{m=-M^*}^{M^*} \sum_{n=|m|}^{N^*} \psi_{mn} P_{mn} (\mu_j) e^{im\lambda_k} \tag{2}$$

$$= \sum_{m=-M^*}^{M^*} \psi_m (\phi_j) e^{im\lambda_k} \tag{3}$$

$$= \psi_o(\phi_j) + \sum_{m=1}^{M^*} (\psi_m (\phi_j) e^{im\lambda_k} + \psi^*_m(\phi_j) e^{-im\lambda_k}) \tag{4}$$

(since $\psi(\lambda_k,\psi_j)$ is real, $\psi_{-m}(\phi_j) = \psi^*_m (\phi_j)$
where $\psi^*_m(\phi_j)$ = complex conjugate of $\psi_m(\phi_j)$)

Compare this with the format of the 'half-complex' Fourier transform

If $\quad x_a = \sum_{b=0}^{B-1} C_b \, e^{2ia\pi b/B}$ and $C_{B-b} = C^*_b$ (i.e. C_o and $C_{B/2}$ are real)

then

$$x_a = C_o + \sum_{b=1}^{\frac{B}{2}-1} \{C_b \, e^{2\pi iab/B} + C^*_b \, e^{-2\pi iab/B}\} + C_{\frac{B}{2}} e^{ia\pi}$$

and

$$C_b = \frac{1}{B} \sum_{a=o}^{B-1} x_a e^{-2ia\pi b/B}$$

Given a field $\psi(\lambda_k, \phi_j)$ on a regular latitude/longitude grid, with

$$\lambda_k = \frac{2\pi k}{NLON} \text{ for } k = 0,1,\ldots NLON-1$$

NLON = number of longitude points

then the Fourier coefficients $\psi_m(\phi_j)$ may be exactly calculated by the transform

$$\psi_m(\phi_j) = \frac{1}{NLON} \sum_{k=o}^{NLON-1} \psi(\lambda_k, \phi_j) e^{-im\lambda_k}$$

$$\text{if } 0 \le m \le M^* \le \frac{NLON}{2} - 1 \qquad (5)$$

(Within the post-processing package, half-complex transforms are used, so that by exploiting the fact that $\psi_{-m} = \psi_m^*$, only the Fourier coefficients for $m \ge o$ need to be calculated explicitly).

The Fourier coefficients $\psi_m(\phi_j)$ may be divided into symmetric and antisymmetric parts with respect to the equator:-

$$\psi_m^S(\phi_j) = \frac{1}{2}(\psi_m(\phi_j) + \psi_m(-\phi_j))$$

$$\psi_m^A(\phi_j) = \frac{1}{2}(\psi_m(\phi_j) - \psi_m(-\phi_j)) \qquad (6)$$

The Legendre functions $P_{mn}(\mu)$ may be represented as trigonometric polynomials with latitude ϕ as argument:-

$$P_{mn}(\mu) = \begin{cases} \sum\limits_{r=\varepsilon 1}^{n}{}^{2} \; P_{mn}^{r} \cos(r\phi) & \text{for } (m+n) \text{ even} \\ \sum\limits_{r=\varepsilon 2}^{n}{}^{2} \; P_{mn}^{r} \sin(r\phi) & \text{for } (m+n) \text{ odd} \end{cases} \qquad (7)$$

where $\sum\limits_{r=\varepsilon 1}^{n}{}^{2}$ means $r = \varepsilon 1, \; \varepsilon 1+2, \; \varepsilon 1+4, \ldots, \; n$ or $n-1$

and

$$\varepsilon 1 = \begin{cases} 0 & \text{for m even} \\ 1 & \text{for m odd} \end{cases} \qquad \varepsilon 2 = \begin{cases} 1 & \text{for m even} \\ 2 & \text{for m odd} \end{cases}$$

So $P_{mn}(\mu)$ is symmetric with respect to the equator when $(m+n)$ is even, and antisymmetric when $(m+n)$ is odd.

From (2)
$$\psi_m(\phi) = \sum_{n=|m|}^{N^*} \psi_{mn} P_{mn}(\mu) \qquad (8)$$
$$= \psi_m^S(\phi) + \psi_m^A(\phi)$$

Using (7)
$$\psi_m^S(\phi) = \sum_{n=|m|}^{N^*}{}^{2} \; \psi_{mn} P_{mn}(\mu) \qquad (9)$$

$$\psi_m^A(\phi) = \sum_{n=|m|+1}^{N^*}{}^{2} \; \psi_{mn} P_{mn}(\mu)$$

since for $n=|m|, n=|m|+2$, etc., $(m+n)$ is even, and $P_{mn}(\mu)$ is symmetric.

Combining (9) and (7) gives

$$
\left.
\begin{aligned}
\psi_m^S(\phi) &= \sum_{r=\varepsilon 1}^{N^*} {}^{2}\ \psi_m^r \cos(r\phi) \\
\psi_m^A(\phi) &= \sum_{r=\varepsilon 2}^{N^*} {}^{2}\ \psi_m^r \sin(r\phi)
\end{aligned}
\right\} \quad (10)
$$

$$
\text{where } \psi_m^r = \sum_{n=r}^{N^*} {}^{2}\ \psi_{mn} P_{mn}^r \qquad r=\varepsilon 1,\ldots\ldots,N^* \qquad (11)
$$

Using the orthogonality relations for trigonometric functions on (10) gives

$$
\psi_m^r = \begin{cases} \dfrac{\delta}{\pi} \displaystyle\int_0^{2\pi} \psi_m^S(\phi) \cos(r\phi)d\phi & r=\varepsilon 1,\varepsilon 1+2,\ldots,N^* \text{ or } N^*-1 \\[2ex] \dfrac{1}{\pi} \displaystyle\int_0^{2\pi} \psi_m^A(\phi) \sin(r\phi)d\phi & r=\varepsilon 2,\varepsilon 2+2,\ldots,N^* \text{ or } N^*-1 \end{cases} \qquad (12)
$$

where

$$\delta = 1 \quad \text{for } r \neq 0$$

$$\delta = \frac{1}{2} \quad \text{for } r = 0$$

The trapezoidal quadrature formula

$$
\frac{1}{\pi} \int_0^{2\pi} f(\phi)\, d\phi = \frac{2}{k} \sum_{j=1}^{k} f(\phi_j) \qquad (13)
$$

(where $\phi_j=\alpha+(j-1)\frac{2\pi}{k}$ and $0 \leqslant \alpha \leqslant \frac{2\pi}{k}$)

is exact for $f(\phi)$ being any trigonometric polynomial of degree $<$ k-1. The polynomials of equation (12) are of degree $\leqslant 2N^*$, so they can be integrated exactly by:-

$$\psi_m^r = \begin{cases} \frac{2\delta}{B} \sum_{j=1}^{B} \psi_m^S(\phi_j) \cos(r\phi_j) & r=\varepsilon 1, \varepsilon 1+2, \ldots \\ \\ \frac{2}{B} \sum_{j=1}^{B} \psi_m^A(\phi_j) \sin(r\phi_j) & r=\varepsilon 2, \varepsilon 2+2, \ldots \end{cases} \tag{14}$$

where $B \geqslant 2N^*+1$, $\phi_j = \alpha + (j-1)\frac{2\pi}{B}$, $0 \leqslant \alpha \leqslant \frac{2\pi}{B}$

For the forecast model grid, $\alpha = 0$ will be used for all fields except v-velocity, which will use $\alpha = \frac{\pi}{B}$.

With these values of α, and if B is chosen to be a multiple of 4, i.e. B = 4*C, equation (14) can be further simplified:-

$$\psi_m^r = \begin{cases} \frac{2\delta}{C} \sum_{j=1}^{D} W_j \, \psi_m^S(\phi_j) \cos(r\phi_j) & r=\varepsilon 1, \varepsilon 1+2, \ldots \\ \\ \frac{2}{C} \sum_{j=1}^{D} W_j \, \psi_m^A(\phi_j) \sin(r\phi_j) & r=\varepsilon 2, \varepsilon 2+2, \ldots \end{cases} \tag{15}$$

where, if $\alpha = 0$, $D = C + 1$

$W_j = \frac{1}{2}$ for $j = 1$ and $j = D$

$W_j = 1$ for $j \neq 1$ and $j \neq D$

and, if $\alpha = \frac{\pi}{B}$, $D = C$

$W_j = 1$ for all values of j .

This simplification is possible because each term in (14) is a trigonometric polynomial of even degree, including only cosines or only sines.

Consider for example the case where $\alpha = 0$ and m is odd. Then $\varepsilon 1 = 1$, and for r odd

$$\cos\left(\frac{2\pi r}{B}\right) = -\cos\left(r\pi - \frac{2\pi r}{B}\right) = -\cos\left(r\pi + \frac{2\pi r}{B}\right) = \cos\left(2r\pi - \frac{2\pi r}{B}\right)$$

and since $\psi_m^S(\phi_j) = \sum_{r=\varepsilon 1}^{N} {}^2 \psi_m^r \cos(r\phi_j)$

$$\psi_m^S\left(\frac{2\pi r}{B}\right) = -\psi_m^S\left(r\pi - \frac{2\pi r}{B}\right) = -\psi_m^S\left(r\pi + \frac{2\pi r}{B}\right) = \psi_m^S\left(2r\pi - \frac{2\pi r}{B}\right)$$

so

$$\psi_m^S\left(\frac{2\pi r}{B}\right)\cos\left(\frac{2\pi r}{B}\right) = \psi_m^S\left(r\pi - \frac{2\pi r}{B}\right)\cos\left(r\pi - \frac{2\pi r}{B}\right)$$

$$= \psi_m^S\left(r\pi + \frac{2\pi r}{B}\right)\cos\left(r\pi + \frac{2\pi r}{B}\right) = \psi_m^S\left(2r\pi - \frac{2\pi r}{B}\right)\cos\left(2r\pi + \frac{2\pi r}{B}\right)$$

Using the orthogonality relations for Legendre functions on (8)

$$\psi_m(\phi) = \sum_{n=|m|}^{N^*} \psi_{mn}(\mu)\ P_{mn}(\mu)$$

gives

$$\psi_{mn} = \frac{1}{2} \int_{-1}^{1} \psi_m(\phi)\ P_{mn}(\mu) d\mu \tag{16}$$

Inserting (10) into (16) gives

$$\psi_{mn} = \begin{cases} \sum_{r=\varepsilon 1}^{N^*} {}^2\, \psi_m^r \frac{1}{2} \int_{-1}^{1} P_{mn}(\mu)\cos(r\phi)d\mu & \text{for } m+n \text{ even} \\ \sum_{r=\varepsilon 1}^{N^*} {}^2\, \psi_m^r \frac{1}{2} \int_{-1}^{1} P_{mn}(\mu)\sin(r\phi)d\mu & \text{for } m+n \text{ odd} \end{cases} \tag{17}$$

And inserting (15) into (17) gives

$$\psi_{mn} = \begin{cases} \sum_{j=1}^{D} \psi_m^S(\phi_j) Z_{mn}(\phi_j) & \text{for } m+n \text{ even} \\ \sum_{j=1}^{D} \psi_m^A(\phi_j) Z_{mn}(\phi_j) & \text{for } m+n \text{ odd} \end{cases} \tag{18}$$

where

$$Z_{mn}(\phi_j) = \begin{cases} \frac{W_j}{C} \sum_{r=\varepsilon 1}^{N^*} {}^2\, \delta R_{mn}^r \cos(r\phi_j) & \text{for } m+n \text{ even} \\ \frac{W_j}{C} \sum_{r=\varepsilon 2}^{N^*} {}^2\, R_{mn}^r \sin(r\phi_j) & \text{for } m+n \text{ odd} \end{cases} \tag{19}$$

and

$$R_{mn}^r = \begin{cases} \int_{-1}^{1} P_{mn}(\mu)\cos(r\phi)d\mu & \text{for } (m+n) \text{ even, } r=\varepsilon 1, \varepsilon 1+2, \ldots \\ \int_{-1}^{1} P_{mn}(\mu)\sin(r\phi)d\mu & \text{for } (m+n) \text{ odd, } r=\varepsilon 2, \varepsilon 2+2, \ldots \end{cases} \tag{20}$$

The coefficients R_{mn}^r are evaluated using Gaussian quadrature, which is exact if N^* Gaussian latitudes are used.

It has been shown so far that the spherical harmonic coefficients may be calculated exactly by this method, providing that the data fitted may be represented exactly by a truncated series of spherical harmonics of the form:

$$\psi(\lambda_k,\phi_j) = \sum_{m=-M^*}^{M^*} \sum_{n=|m|}^{N^*} \psi_{mn} P_{mn}(\phi_j) e^{im\lambda_k}$$

where $0 \leqslant M^* \leqslant N^*$

and providing that certain relations between the grid and the truncation limits are satisfied.

On the model grid, data is given at the points

$\lambda_k = (k-1)\Delta\lambda$ for $k=1,2,..4Q$ (for all fields except u)

$= (k-\frac{1}{2})\Delta\lambda$ for $k=1,2,..4Q$ (u only)

$\phi_j = \pm(j-1)\Delta\phi$ for $j=1,2,..(Q+1)$ (for all fields except v)

$= \pm(j-\frac{1}{2})\Delta\phi$ for $j=1,2,..Q$ (v only)

with $\Delta\lambda = \Delta\phi = \frac{\pi}{2Q}$

and Q = NLON/4 where NLON = number of longitude points

= (NOREC-1)/2 where NOREC = number of latitude rows

From (5), the Fourier transform will be exact if

$$M^* \leqslant 2Q - 1 = \text{NLON}/2-1$$

Equation (18) will be exact if

$$2N^* \leq 4Q - 1$$

i.e. $N^* \leq (\text{NLON}-1)/2$ and $N^* \leq \text{NOREC}-1-\frac{1}{2}$

so we need

$$0 \leq M^* \leq N^* \leq \begin{cases} (\text{NLON}-1)/2 \\ \text{NOREC}-2 \end{cases}$$

In general, grid point fields will not satisfy the above restrictions, since the number of grid points will always be larger than the number of spherical harmonics used. Instead the function $\psi'(\lambda,\phi)$ will be fitted to the data, where

$$\psi'(\lambda,\phi) = \sum_{m=-M}^{M} \sum_{n=|m|}^{N} \psi_{mn} P_{mn}(\phi) e^{im\lambda}$$

with $M \leq M^*$, $N \leq N^*$ and $M, N \leq \begin{cases} (\text{NLON}-1)/2 \\ \text{NOREC}-2 \end{cases}$

$\psi'(\lambda,\phi)$ can be shown to be, in some sense, a least squares fit to the data.

Within the post-processing package, triangular truncation is used, i.e. $M = N = T$, say.

2.1 Velocity fields

The method described above is modified for the calculation of spherical harmonic coefficients for the velocities. First the coefficients for divergence, D, and vorticity, ζ, are calculated from the grid point values of u and v. Both divergence and vorticity are well defined at the poles. The coefficients for u and v are then derived from the divergence and vorticity coefficients.

In the forecast model, the u-velocity components are defined at the points (λ_k^u, ϕ_j^u), where

$$\lambda_k^u = (k-\tfrac{1}{2})\Delta\lambda \quad \text{for } k=1,2,\ldots 4Q$$

$$\phi_j^u = \pm(j-1)\Delta\phi \quad \text{for } j=1,2,\ldots (Q+1)$$

and $\Delta\lambda = \Delta\phi = \dfrac{\pi}{2Q}$

The v-velocity components are defined at the points (λ_k^v, ϕ_j^v),

where

$$\lambda_k^v = (k-1)\Delta\lambda \quad \text{for } k=1,2,\ldots 4Q$$

$$\phi_j^v = \pm(j-\tfrac{1}{2})\Delta\phi \quad \text{for } j=1,2,\ldots Q$$

Let $U = u\cos(\phi)$ and $V = v\cos(\phi)$, then

$$\zeta = \frac{1}{a(1-\mu^2)} \left\{\frac{\partial V}{\partial\lambda} - (1-\mu^2)\frac{\partial U}{\partial\mu}\right\} \qquad (21)$$

$$D = \frac{1}{a(1-\mu^2)} \left\{\frac{\partial U}{\partial\lambda} + (1-\mu^2)\frac{\partial V}{\partial\mu}\right\}$$

where a = radius of earth

$$\text{Then } \zeta_{mn} = \frac{1}{2a}\int_{-1}^{1} \{imV_m P_{mn} - U_m H_{mn}\} \frac{d\mu}{1-\mu^2}$$

$$D_{mn} = \frac{1}{2a}\int_{-1}^{1} \{imU_m P_{mn} + V_m H_{mn}\} \frac{d\mu}{1-\mu^2} \qquad (22)$$

where $H_{mn} = -(1-\mu^2)\dfrac{dP_{mn}}{d\mu}$

The coefficients D_{mn} and ζ_{mn} can be calculated using a modified version of (18).

$$D_{mn} = \begin{cases} \sum_{j=1}^{Q+1} imU_m^S(\phi_j^u)Z_{mn}^I(\phi_j^u) + \sum_{j=1}^{Q} V_m^A(\phi_j^v)Z_{mn}^{II}(\phi_j^v) & \text{for } m+n \text{ even} \\ \sum_{j=1}^{Q+1} imU_m^A(\phi_j^u)Z_{mn}^I(\phi_j^u) + \sum_{j=1}^{Q} V_m^S(\phi_j^v)Z_{mn}^{II}(\phi_j^v) & \text{for } m+n \text{ odd} \end{cases} \tag{23}$$

$$\zeta_{mn} = \begin{cases} \sum_{j=1}^{Q} imV_m^S(\phi_j^v)Z_{mn}^I(\phi_j^v) - \sum_{j=1}^{Q+1} U_m^A(\phi_j^u)Z_{mn}^{II}(\phi_j^u) & \text{for } m+n \text{ even} \\ \sum_{j=1}^{Q} imV_n^A(\phi_j^v)Z_{mn}^I(\phi_j^v) - \sum_{j=1}^{Q+1} U_m^S(\phi_j^u)Z_{mn}^{II}(\phi_j^u) & \text{for } m+n \text{ odd} \end{cases} \tag{24}$$

where

$$Z_{mn}^I(\phi_j) = \begin{cases} \frac{w_j}{aQ} \sum_{r=\varepsilon 1}^{N^*_2} \delta R_{mn}^{I\ r} \cos(r\phi_j) & \text{for } m+n \text{ even} \\ \frac{w_j}{aQ} \sum_{r=\varepsilon 2}^{N^*_2} R_{mn}^{I\ r} \sin(r\phi_j) & \text{for } m+n \text{ odd} \end{cases} \tag{25}$$

$$Z_{mn}^{II}(\phi_j) = \begin{cases} \frac{w_j}{aQ} \sum_{r=\varepsilon 2}^{N^*_2} R_{mn}^{II\ r} \sin(r\phi_j) & \text{for } m+n \text{ even} \\ \frac{w_j}{aQ} \sum_{r=\varepsilon 1}^{N^*_2} \delta R_{mn}^{II\ r} \cos(r\phi_j) & \text{for } m+n \text{ odd} \end{cases} \tag{26}$$

With

$$w_j = \begin{cases} 1 \text{ for } j \neq 1 \\ \frac{1}{2} \text{ for } j = 1 \text{ at } \phi_j^u \\ 1 \text{ for } j = 1 \text{ at } \phi_j^v \end{cases} \quad \text{and} \quad \delta = \begin{cases} \frac{1}{2} \text{ for } r = 0 \\ 1 \text{ for } r \neq 0 \end{cases}$$

The coefficients R_{mn}^{Ir} and R_{mn}^{IIr} are determined by Gaussian quadrature of the following integrals:-

$$R_{mn}^{Ir} = \begin{cases} \int_{-1}^{1} \frac{P_{mn}(\mu)}{1-\mu^2} \cos(r\phi)d\mu & \text{for } m+n \text{ even,} \\ & r=\varepsilon 1,\ \varepsilon 1+2, \ldots,\ N^* \text{ or } N^*-1 \\ \int_{-1}^{1} \frac{P_{mn}(\mu)}{1-\mu^2} \sin(r\phi)d\mu & \text{for } m+n \text{ odd,} \\ & r=\varepsilon 2, \varepsilon 2+2, \ldots, N^* \text{ or } N^*-1 \end{cases} \quad (27)$$

$$R_{mn}^{IIr} = \begin{cases} -\int_{-1}^{1} \frac{dP_{mn}}{d\mu} \sin(r\phi)d\mu & \text{for } m+n \text{ even,} \\ & r=\varepsilon 2, \varepsilon 2+2, \ldots,\ N^* \text{ or } N^*-1 \\ -\int_{-1}^{1} \frac{dP_{mn}}{d} \cos(r\phi)d\mu & \text{for } m+n \text{ odd,} \\ & r=\varepsilon 1, \varepsilon 1+2, \ldots,\ N^* \text{ or } N^*-1 \end{cases}$$

The coefficients U_{mn} and V_{mn} may be derived using the following relations:-

If $\zeta = \nabla^2\psi$, then $\zeta_{mn} = \frac{-n(n+1)}{a^2} \psi_{mn}$

If $D = \nabla^2\alpha$ then $D_{mn} = \frac{-n(n+1)}{a^2} \alpha_{mn}$

$$U = \left(\frac{\partial\alpha}{\partial\lambda} + (\mu^2-1) \frac{\partial\psi}{\partial\mu} \right) \frac{1}{a}$$

$$V = -(\mu^2-1)\frac{\partial\alpha}{\partial\mu} + \frac{\partial\psi}{\partial\lambda})\frac{1}{a}$$

$$H_{mn}(\mu) = (\mu^2-1)\frac{dP_{mn}}{d\mu}$$

$$= nF_{m,n+1}P_{m,n+1} - (n+1)F_{m,n}P_{m,n-1}$$

$$\text{with } F_{mn} = \left(\frac{n^2-m^2}{4n^2-1}\right)^{\frac{1}{2}} \tag{28}$$

$$\text{and } G_{mn} = \frac{-m}{n(n+1)}$$

$$\text{so } U_{mn} = a\left(-\frac{1}{n}F_{mn}\zeta_{m,n-1} + iG_{mn}D_{mn} + \frac{1}{n+1}F_{m,n+1}\zeta_{m,n+1}\right)$$

(29)

$$V_{mn} = a\left(\frac{1}{n}F_{mn}D_{m,n-1} + iG_{mn}\zeta_{mn} - \frac{1}{n+1}F_{m,n+1}D_{m,n+1}\right)$$

If a subset of spherical harmonic coefficients are calculated, with triangular truncation T, i.e.

$$\hat{\zeta} = \sum_{m=-T}^{T}\sum_{n=|m|}^{T}\zeta_{mn}P_{mn}(\lambda,\mu)e^{im\lambda}$$

$$\hat{D} = \sum_{m=-T}^{T}\sum_{n=|m|}^{T}D_{mn}P_{mn}(\lambda,\mu)e^{im\lambda}$$

then the derived velocity fields are

$$\hat{u} = \frac{1}{\cos(\phi)}\sum_{m=-T}^{T}\sum_{n=|m|}^{T+1}U_{mn}P_{mn}(\lambda,\mu)e^{im\lambda}$$

(30)

$$\hat{v} = \frac{1}{\cos(\phi)}\sum_{m=-T}^{T}\sum_{n=|m|}^{T+1}V_{mn}P_{mn}(\lambda,\mu)e^{im\lambda}$$

where

$$U_{m,T+1} = a\left(-\frac{1}{T+1} F_{m,T+1}\zeta_{m,T}\right)$$

$$V_{m,T+1} = a\left(\frac{1}{T+1} F_{m,T+1} D_{m,T}\right)$$

and $$U_{m,T} = a\left(-\frac{1}{T} F_{m,T}\zeta_{m,T-1} - \frac{im}{T(T+1)} D_{m,T}\right)$$

$$V_{m,T} = a\left(\frac{1}{T} F_{m,T} D_{m,T-1} - \frac{im}{T(T+1)}\zeta_{mT}\right)$$

It can be shown that equation (29), defining u and v, is also valid at the poles.

For any value of m, the T-m+1 coefficients D_{mn} and ζ_{mn} define T-m+2 coefficients of U_{mn} and V_{mn}, so that by elimination of D and ζ coefficients from (28), relations between U and V coefficients may be derived. In particular, when m = 0 the following relations hold:-

$$U_{o,T+1} = -\frac{1}{\sqrt{(2T+3)}} \sum_{n=\varepsilon 1}^{T-1}{}^{2} \sqrt{(2n+1)}U_{on}$$

$$V_{o,T+1} = -\frac{1}{\sqrt{(2T+3)}} \sum_{n=\varepsilon 1}^{T-1}{}^{2} \sqrt{(2n+1)}V_{on} \qquad (31)$$

$$U_{o,T} = -\frac{1}{\sqrt{(2T+1)}} \sum_{n=\varepsilon 2}^{T-1}{}^{2} \sqrt{(2n+1)}U_{on}$$

$$V_{o,T} = -\frac{1}{\sqrt{(2T+1)}} \sum_{n=\varepsilon 2}^{T-1}{}^{2} \sqrt{(2n+1)}V_{on}$$

where, if T is odd, $\varepsilon 1 = 0$ and $\varepsilon 2 = 1$
and if T is even, $\varepsilon 1 = 1$ and $\varepsilon 2 = 0$

At the poles, $\dfrac{P_{mn}(\phi = \pm\frac{\pi}{2})}{\cos(\phi)} = 0$ for $m > 1$

It can be shown that $\lim\limits_{\phi \to \pm\frac{\pi}{2}} \sum\limits_{n=o}^{T+1} U_{o,n} \dfrac{P_{o,n}(\phi)}{\cos(\phi)} = 0$

i.e. $\sum\limits_{n=o}^{T+1} U_{on} \dfrac{\partial P_{o,n}(\phi)}{\partial \cos(\phi)} = 0$ when $\phi = \pm\frac{\pi}{2}$

$$\sum_{n=o}^{T+1} U_{on} \frac{\partial P_{on}(\phi)}{\partial \cos(\phi)} = \sum_{n=o}^{T+1} \frac{1}{\sin(\phi)\cos(\phi)} U_{on}$$

$$\times \left[nF_{o,n+1}P_{o,n+1} - (n+1)F_{o,n}P_{o,n-1} \right] \qquad (32)$$

Substituting the relations (30) into (31) and using

$$P_{o,n} = \frac{1}{F_{mn}} (\mu P_{o,n-1} - F_{o,n-1} P_{o,n-2})$$

it can be shown that each term in(32) is proportional to $\cos(\phi)$, and thus vanishes at the poles.

So at the poles

$$u(\phi) = \sum_{n=1}^{T+1} U_{1n} \frac{P_{1n}(\phi)}{\cos(\phi)} e^{i\lambda} \qquad (33)$$

$$v(\phi) = \sum_{n=1}^{T+1} V_{1n} \frac{P_{1n}(\phi)}{\cos(\phi)} e^{i\lambda}$$

3. Forecast-called version

This section describes in detail the forecast-called version of the first part of the post-processing package, in the order in which it is executed. Subroutines from the forecast model are marked (M), and are described in (Haseler and Burridge, 1977).

3.1 Subroutine PRESET (M)

<1.1> I/O unit numbers used by the post-processing package are preset (units 15,16,17,18,19,60).

<1.6> Logical switches are set

NLANAL = false (forecast, not analysis, data is to be post-processed)

NLSTAL = false (this is the forecast-called version, not the stand-alone version)

NLINI = false (forecast, not initialisation, type file names are to be constructed in the operational version)

3.2 Subroutine DATA (M)

<7.1> Call INISTP to set post-processing parameters

3.3 Subroutine INISTP

<1> Call PRESTP to preset post-processing parameters with default values

<2> Read the namelist POSTIN. Fig. 3.1 describes the variables of POSTIN, and their default values.

<3> Calculate NPPTR and NPSTEP, where

NPWTIM(NPPTR) = NPSTEP

NPWTIM(200) contains the step numbers at which post-processing is to be done. NPSTEP is the first element of NPWTIM such that NPSTEP$\geq$NSTEP, where NSTEP is the current forecast step.

<4.5> In the spring experiment and operational versions of the post-processing, read data cards containing the parameters to assign

the work files and output files to specific disks. By placing files on different disks, controlled by different disk controllers, the I/O efficiency can be improved. It is also more efficient if post-processing files are not on the same disks as forecast work files.

<4.7> For the spring experiment version of the model, read data cards giving the VSN and SN of the private disk to which post-processed files will be disposed.

<7.2> Call INITXX. This initialises parameters used in the vertical interpolation from sigma to pressure levels.

<7.4> Call HAFFT. This initialises parameters used by the fast Fourier transforms in the second part of the package.

<7.4> Call MAKEDS. Calculate coefficients F_{mn} and G_{mn} (defined by equation 28 of Section 2, used in the generation of u and v spherical harmonic coefficients), and store them in the arrays DD and SS from COMSH1.

<7.4> If NLCALC= true, call MAKEZZ. Generate the following functions used in the calculation of spherical harmonic coefficients:

(a) $Z_{mn}(\phi_j^T)$ - defined by equation 19 of Section 2 and given at latitudes of T grid points.

(b) $Z^I_{mn}(\phi_j^u)$, $Z^I_{mn}(\phi_j^v)$ - defined by equation 25 of Section 2, and given at latitudes of both u and v grid points.

(c) $Z^{II}_{mn}(\phi_j^u)$, $Z^{II}_{mn}(\phi_j^v)$ - defined by equation 26 of Section 2 and given at latitudes of both u and v grid points.

These functions are expensive to calculate. They depend only on the resolution of the model grid and the triangular truncation used in fitting the spherical harmonics. The first time a particular resolution and truncation are used, NLCALC should be set to true, so that these functions are calculated, and they should be saved as permanent files.

Thereafter, by setting NLCALC = false, they need not be recalculated.

<7.4> If NLCALC = true, call MAKELG. Calculate Legendre functions at the latitude of the output grid, to be used in extracting fields on the output grid from their spherical harmonic coefficients. Again, these functions are expensive to calculate, and need only be made once, for any output grid resolution and triangular truncation.

<7.5> Call REORDR to rearrange the fields selected for post-processing by the user to the order most convenient for the second part of the post-processing package. Section 5 describes in detail how the fields are rearranged, and how control arrays are constructed to describe the new order of the data.

<7.6> For the operational version of the model, subroutine OPNPP1 is called to assign the work files to particular devices, and to generate operational-type file names.

3.4 Subroutine LINEMS (M)

<2.9> Call SITOPR if it is a post-processing time step, then update the pointer to the next post-processing step. In the operational version of the post-processing, call subroutine CLSPP1 to internally save the work files. In the spring experiment version, call subroutine FGPOST to save the work files and launch a job to do the second part of the post-processing.

<3.2> If post-processing is requested at the first or second time-step of a model run, call SITOPR, then update the pointer to the next post-processing step.

3.5 Subroutine SITOPR

Generate the work file which will be used as input to the second part of the post-processing package. Section 6 contains a detailed description of the work file.

The user may select 4 types of fields to be processed:-

(a) fields on multiple levels, to be interpolated horizontally using spherical harmonics

(b) fields on single levels, to be interpolated horizontally, using spherical harmonics

(c) fields on single levels on the model grid, which are not to be interpolated either horizontally or vertically. (These will usually be surface fields. They will be referred to in future as uninterpolated fields).

(d) diagnostics fields

Field types (a) and (b) are interpolated vertically from sigma to pressure levels, if the data comes from a forecast model, and if the variable NVINT is non-zero. Analysis data is already on pressure levels, and is not vertically interpolated.

Figure 3.5.1 gives a list of all the fields which can be handled by the post-processing, together with the code numbers by which they are represented.

<1.01> Before the first row of data has been written, update the parameters describing the date and time of the data.

<1.03> Before the first row of data has been written, write 7 common blocks, as separate records, to the work file on unit NPOUT.

<1.1> Find the first field to be processed. This will be the first multi-level field (type (a) above) if there are any, or the first single level field (type (b) above).

<1.2> If there are no fields of type (a) or (b), the first field to be processed will be the first uninterpolated field.

<1.3> If there are no fields of type (a), (b) or (c) the diagnostic fields will be processed first.

<2.1> The area of blank common starting from the displacement NLINE2(2) is used as work space by SITOPR. The work space is laid out with fields starting at the following displacements:-

(i) IPNVP1 - the area in which fields derived at the (NLEV+1) sigma half-levels are stored (e.g. geopotential, part of the vertical velocity).

(ii) IOMEG - work space used in the calculation of vertical velocity and relative humidity fields

(iii) IPC - work space used by the vertical interpolation routines

(iv) IWRITE - the fields which are to be written to the work file are built up in a buffer, starting at displacement IWRITE.

(v) ISPLWK1, ISPLWK2, ISPLWK3, ISPLWK4 - the work space used by the optimised spline fitting routines, of total length 12*NLP2. This work space is placed at the end of the NLINE2(2) buffer (which is (12*NLEV+30)*NLP2 words long), since it may be overwritten by the uninterpolated and diagnostics fields.

The fields which are to be fitted by spline must be stored between IWRITE and ISPLWK1, i.e. MFDIN*NLP2⩽(9*NLEV+16)*NLP2

The fields which are to be interpolated + uninterpolated fields + diagnostics fields must be stored between IWRITE and the end of the NLINE2(2) buffer, i.e.

(MFDIN+N2D+NDIAWK)*NLP2⩽(9*NLEV+28)*NLP2

The tests for valid numbers of fields are done in INISTP <7.5>.

<2.27> The code of the field to be processed is stored in ICODE, and the level (converted to pascals) is stored in ILEVEL.

<2.4> The start address of the highest level of the current field is stored in IPFLD. If the field is relative humidity, it is calculated at all the model σ-levels by subroutine RELHMF. If the field is vertical velocity, it is processed in 2 scans, on the first scan, part of it is calculated by subroutine OMEG1. On the second scan, the rest is calculated by subroutine OMEG2. If the field is cloud cover, it is calculated by subroutine CLCOV. If the field is u or v at 10 metres or T or T_d at 2 metres, it is calculated by subroutine SURPAR.

<3> If the field being processed is to be interpolated vertically from sigma to pressure levels, subroutine ANALYS is called. If cubic splines are being used to fit the data in the vertical, ANALYS uses data at all the sigma levels to calculate the coefficients of the splines, and store them in the work array IPC. For multi-level fields, ANALYS need only be called once, since the same array of coefficients in IPC can be used to extract data at any pressure level. Accordingly all the levels of a multi-level field are processed by SITOPR, before ANALYS is called again with a different field as input. Similarly, if linear interpolation is used in the vertical, ANALYS need only be called once for each multi-level field.

<4.0> If the field being processed is to be interpolated vertically from sigma to pressure levels, subroutine EVALUD is called to extract the data at pressure level ILEVEL, using as input the array IPC constructed by ANALYS.

<4.1> If mean sea level pressure is the field requested, it is calculated by subroutine SEALP.

<4.2> If the field just processed was the first scan of the vertical velocity, the second scan is initiated.

<4.3> If the field just processed was the second scan of the vertical velocity, the 2 parts are added together.

<4.4> If the field just processed was the relative humidity, any values calculated to be greater than 100% are reduced to 100%.

<4.5> If the field currently being processed is an uninterpolated field, of type (c), or a diagnostics field, it is copied straight into the output buffer.

The following uninterpolated fields are scaled:
large scale rain (*Ø.5); convective rain (*Ø.5);
snow fall (*Ø.5); boundary layer dissipation ($*\frac{1}{g}$);
surface sensible heat flux ($* \, c_p \frac{(1-\sigma_{NLEV-\frac{1}{2}})}{g}$);
surface latent heat flux ($* \, L \frac{(1-\sigma_{NLEV-\frac{1}{2}})}{g}$);
surface stress ($* \frac{(1-\sigma_{NLEV-\frac{1}{2}})}{g}$)

<5.1> The next field to be processed is found. The fields are processed by SITOPR in the order

(i) all levels of first multi-level field (type a)

(ii) all levels of next multi-level field

. . . . .

(iii) all single-level fields (type b)

(iv) all uninterpolated fields (type c)

(v) all diagnostic fields

The fields are stored on the work file in the order most convenient for the second part of the post-processing package, which is:-

(i) all multi-level fields at first level

(ii) all multi-level fields at next level

. . . . .

(iii) all single level fields

(iv) all uninterpolated fields.

(v) all diagnostics fields.

<5.4> When all the fields for the current row have been built up in the output buffer, they are written to the work files. The first quarter of the fields are written to unit NPOUT; the second quarter to (NPOUT+1); the third quarter to (NPOUT+2) and the remainder to (NPOUT+3). If there are less than 4 fields, they are all written to NPOUT.

4. Stand-alone version

The stand-alone version of the first part of the post-processing package may take as input an analysis file, or a forecast history file at a single time level, or 2 forecast history files at adjacent time levels (the second history file is required for certain physics diagnostics fields). Much of the code used by the forecast-called version is also used by the stand-alone version, but the main differences are outlined below.

4.1 Subroutine OUTPAC(KIN,KOUT,KCARD,KPRINT)

The stand-alone version is invoked by calling OUTPAC, with the arguments

KIN = unit number of input analysis or forecast file (if there are 2 forecast files, then time T will be on unit KIN and time T+1 on unit KIN+1)

KOUT = unit number of output work file

KCARD = unit number of card input

KPRINT = unit number of print output

<1.1> Read a data card to determine the number and type of input file(s), where the card has the format (9X,1R1,I10), and

F in column 10 means an analysis file

T in column 10 and 1 in column 20 means 1 forecast history file

T in column 10 and 2 in column 20 means 2 forecast history files

<1.2> For an analysis file, skip the first record, which is a file descriptor record.

<1.15> In the operational version of the post-processing, subroutine OPNPP1 is called to attach internally the initial data file(s).

<1.3> Read the first data descriptor record. For an analysis file, call DDANAL to construct the forecast model's common block COMHKP.

<1.4> Call INISDS to construct the forecast model's common block COMSDS (mainly with dummy variables).

<1.5> Initialise various common variables, including in particular NLINE1 and NLINE2 which define the displacements of the I/O buffers, so that the addresses of fields may be built up in the same way in subroutine SITOPR for both the forecast-called and stand-alone versions.

<1.7> Initialise the pointers NLINPP(1) and (2) to 2 output buffers, which will be used alternately to permit overlapped output and computation. In the forecast-called version, there is insufficient space for a second output buffer, so it is not possible to achieve this overlap.

<1.8> Call INISTP (as in Section 3.3) to initialise the post-processing parameters.

<2.1> Scan from north to south, reading the data. The input buffers are cycled in the same way as those for the forecast model, i.e.

NLINE1(1) = start address of row NROW-1, to the north of the current row

NLINE1(2) = start address of current row, NROW

NLINE1(3) = start address of row NROW+1, to the south of the current row

NLINE1(4) = start address of row NROW+2, 2 rows to the south of the current row. The read for the data of this row is overlapped with the processing of the data for row NROW.

<2.3> Call SITOPR to construct the output work file record for row NROW.

<2.5> In the operational version, subroutine CLSPP1 is called to save internally the work files

4.2 Subroutine SITOPR

If a forecast file (or 2 forecast files at adjacent time levels) is being processed, then SITOPR is executed as described in Section 3.5. Analysis fields are given initially on pressure levels, so that fields which are to be fitted by spherical harmonics do not have to be vertically interpolated as well. For an analysis file, the following separate code is executed:-

<7.1>,<7.2> Find the displacement of the highest level of the field selected (analysis files are arranged in a different order to forecast files)

<7.3> Except for surface fields, the displacement of the level selected is found.

<7.5> The field is copied to the output buffer, with a spare word before the first word, and a spare word after the last word. Although the input analysis data is not wrapped, analysis fields on the work file now occupy the space which they would need if they were wrapped.

<7.6> Surface pressure is converted to pascals. Forecast pressures are held in pascals, while analysis files store pressures in millibars.

<7.6> If the field selected was relative humidity, it is generated by subroutine RELHMA.

<7.9> The displacements of analysis error fields are calculated.

5. Reordering fields

The method used to fit spherical harmonics to the velocity fields is first to fit the divergence and vorticity fields, using grid point values of both u and v, and then to derive the u and v coefficients from the divergence and vorticity coefficients. This means that if any of u, v, vorticity or divergence is selected for post-processing, then both u and v (but not vorticity or divergence) must be written to the work file. As a result, there are not necessarily the same number of fields on the work file as there are on the output post-processing files which are to be sent to the Cyber.

The fields are classified as 'velocity' fields (u, v, vorticity or divergence) or 'scalar' fields (all other field types). They are not necessarily processed in the order given by the user, but may be reordered to simplify the control of the fitting of the spherical harmonics. The work file contains first the fields on multiple levels, which are to be fitted with spherical harmonics; then the fields on single levels which are to be fitted with spherical harmonics; then the uninterpolated fields; then the diagnostics fields. The multi-level fields are stored by level on the work file, i.e. with first all the fields at the first level, then all the fields at the second level, and so on. The fields at each level are reordered so that all the scalar fields come at the beginning, followed by all the velocity fields. The single-level fields are also reordered, with first all the scalar fields, then all the velocity fields. The uninterpolated fields are not reordered, but are stored in the order requested by the user.

The routines which fit the spherical harmonics have to decide how many fields may be fitted at the same time in the space available. To do this, the fields are split into groups, described by the control array NPTAR. NPTAR(1) contains the number of groups (if NPTAR(1) = 0, there are no fields to be fitted by spherical harmonics, just uninterpolated fields to be processed). A 'group' consists of

NPLEV levels of data, with each level containing NSCAL scalar fields and NVEL input velocity fields. To describe the N^{th} group,

NPTAR (3*N-1) = NSCAL, the number of scalar fields at each level

NPTAR (3*N) = NVEL, the number of velocity fields on the input work file at each level (either NVEL = 0 if there are no velocities in the N^{th} group

or NVEL = 2 (both u and v are on the input work file))

NPTAR (3*N+1) = NVELO, the number of velocity fields to be output to the post-processing files at each level
(where NVELO = 0 means no velocities
NVELO = 1,2,3 or 4 for any or all of u, v, vorticity and divergence)

The first group contains the multi-level fields. The next group (or first group, if there are no multi-level fields) contains all the scalar single-level fields, plus the first single-level velocity field (if there are any). There is a group for each remaining single-level velocity field. If NPLEV is the number of levels of data in each group, then NPLEV=1, unless the group contains the multi-level fields, when NPLEV = NMLV (where NMLV is the number of levels at which multi-level fields are to be processed).

Section 8 describes in detail how NOLV, the number of levels of data within a group which may be fitted in a single scan, is calculated. At least one scan is required to fit all the fields within a group, and if NOLV < NPLEV, several scans are required.

Several control arrays are built up in subroutine REORDR to describe the reordered data. MHAIN(200) describes the contents of the work file, in the form most convenient for the spherical harmonic fitting routines. It contains the field codes for all the groups in the order

(i) codes for scalar fields in first group

(ii) codes for velocity fields in first group

. . . .

(iii) codes for scalar fields in n^{th} group

(iv) codes for velocity fields in n^{th} group

. . . .

If a group contains fields at more than one level, the codes are not repeated in MHAIN.

MHAOUT(200) describes the fields which have been fitted by spherical harmonics, and are to be sent to the Cyber on a post-processing output file. Like MHAIN, it contains the field codes for scalar and velocity fields within each group, without repetition for fields held at more than one level. The only difference between MHAIN and MHAOUT is that the velocities on the input work file may not be the same as those on the output post-processing file.

NCL(2,200) is the control array used on the Cyber to determine the contents of the output post-processing file which contains fields fitted by spherical harmonics.

NCL(1,J) = code of J^{th} field
NCL(2,J) = level of J^{th} field (in mb*10, or model σ-level number, if NVINT=0)

If fields are repeated at several levels, then they have several entries in NCL.

NCLIN(2,200) is a control array which is not used by the post-processing package, but has been added so that other programs may more easily determine the contents of the work file.

NCLIN(1,J) = code of J^{th} field on work file

NCLIN(2,J) = level of J^{th} field on work file.

If fields are repeated at several levels, then they have several entries in NCLIN.

The uninterpolated fields are described by the array NGPCL(2,20), where

NGPCL(1,J) = code of J^{th} field

NGPCL(2,J) = level of J^{th} field

6. The post-processing work file

The work file has 7 records containing common blocks, followed by a data record for each row. The contents of all the common blocks are described in Section 10. The common blocks are:-

- (i) COMHKP, of length 925 words
- (ii) COMSDO, length 34 words
- (iii) COMGPH, length 45 words
- (iv) COMSHH, length 415 words
- (v) COMSH1, length 8716 words
- (vi) COMHDO, length 16 words.
- (vii) COMDIA, length 422 words

There follow NOREC records, each of length (MFDIN+N2D+NDIAWK)*NLP2

where

NOREC (from COMHKP)	=	number of latitude rows
MFDIN (from COMSH1)	=	number of fields to be fitted by spherical harmonics
N2D (from COMGPH)	=	number of uninterpolated fields
NLP2 (from COMHKP)	=	size of a wrapped field of data (number of longitude points + 2)
NDIAWK (from COMDIA)	=	number of diagnostics fields

If (MFDIN+N2D+NDIAWK)≥4, the work file is split into 4 separate files, which are positioned on disks controlled by 4 different disk controllers, to improve I/O transfer rates. In this case, the first file contains the 7 common blocks, followed by NOREC records of length

((MFDIN+N2D+NDIAWK)/4)*NLP2 (i.e. the first (MFDIN+N2D+NDIAWK/4 fields). The second and third files contain NOREC records of length ((MFDIN+N2D+NDIAWK)/4)*NLP2. The fourth file contains NOREC records of length

((MFDIN+N2D+NDIAWK) - 3*((MFDIN+N2D+NDIAWK)/4))*NLP2

(i.e. the remaining fields)

If the first file is on unit NPOUT, then the second, third and fourth files will be on units NPOUT+1, NPOUT+2 and NPOUT+3 respectively.

When the data is read back in the second part of the post-processing package, only the fields needed for a particular scan are read, so that all 4 sections of the work file do not necessarily have to be read in every time. This is possible because the data is stored on the work file in the order in which it is used by the second part of the post-processing package, rather than the order in which the work file is built up by the first part.

Each data record contains MFDIN fields which are to be fitted by spherical harmonics (described by the control array NCLIN, see Section 5), followed by N2D uninterpolated fields (described by the control array NGPCL, also defined in Section 5), followed by NDIAWK diagnostics fields.

The file is read using BUFFER IN.

7. The second part of the post-processing package

The second part of the post-processing package is a separate job which takes as input the work file generated by the first part, and the constants files created by MAKEZZ and MAKELG (see Section 3.3), and produces 4 types of output file, described in Section 9.

7.1 Subroutine HACNTL

The second part of the post-processing package is invoked by calling HACNTL.

<1.01> Read from a data card with format I10 the unit number, NPOUT, of the work file (or the first file, if it has been split into 4 parts). This should be the same as was used to create the work file.

<1.01> Read the 7 common blocks from the start of NPOUT.

<1.03> Initialise the creation data and time for the output files. Convert the date in COMHKP for forecast files from century days to the form $YY*10^4+MM*10^2+DD$. This format is already used by analysis files.

<1.3> Call SPANAL to decide how many fields may be processed in the current scan. See Section 8 for a detailed description of the layout of the fields, and the algorithms used to decide how many fields may be processed in each scan.

<2.1> Call DISINI to initialise the arrays NDISGR and NDISSH (from COMSH2) containing the displacements in blank common of the input grid-point fields and spherical harmonic coefficients respectively for the current scan. The displacements are given for complex fields, since complex arithmetic is used in the calculation of the spherical harmonic coeffic-

ients. The variable NDIS2D, which defines the real (i.e. not complex) displacement in blank common of the start of the buffer for building up uninterpolated fields for output, is also defined. The variable NDISDI, defining the real displacement of the buffer for building up diagnostics fields for output, is defined.

<2.2> A work file record (or 4 records, if the file has been split into 4 parts) contains all the fields for a single row. The fields which are being processed in the current scan are wanted at all rows. Accordingly, for each row from north to south, a work file record (or records) is read, and the fields to be processed are copied into the area in which complete fields are being constructed. If the work file has been split into 4 parts, only the parts containing data for the current scan are read.

<2.4> The velocity fields are multiplied by cos(latitude), since it is U = ucos(lat) and V = vcos(lat) which are used to derive the divergence and vorticity spherical harmonic coefficients.

<2.7> If uninterpolated fields are to be processed in this scan, they are copied from the buffer containing the work file record for the current row into the area in which the complete fields are being constructed.

<2.71> If diagnostics fields are to be processed in this scan, they are copied from the buffer containing the work file record for the current row into the area in which the complete fields are being constructed.

<2.73> Diagnostics codes are extracted and stored in the array MDIACD in COMDIA. There are up to NDIMAX groups of diagnostics, where NDIMAX=NLON/4. Each group of diagnostics contains 4 fields, each of length NDIAWK*NOREC. Associated with each group of diagnostics are 6 codes. On the forecast file, the J^{th} code for the K^{th} group is held in the last wrap-around point of the J^{th} level of diagnostics of the K^{th} row. In <2.73>, these codes are extracted from the wrap-around points

and stored in MDIACD(6,NDIMAX). If both MDIACD(1,K)=0 and MDIACD(2,K)=0, all 4 fields in the K^{th} group contain zeros, and later on, in subroutine OUTDIA, the entire group will be skipped (i.e. not written to the diagnostics output file).

The number of land points in the K^{th} row is extracted from the last wrap-around point of the 7^{th} level of the K^{th} row and stored in MLAND(K), in COMDIA.

<2.8> If both uninterpolated fields and fields fitted by spherical harmonics are being processed in the current scan, subroutine OUT2D is called to output the complete uninterpolated fields, before the space they occupy is overwritten by the work space for the fast Fourier transform. See Section 9 for a detailed description of the output file for the uninterpolated fields.

<2.91> If both diagnostics fields and fields fitted by spherical harmonics are being processed in the current scan, subroutine OUTDIA is called to output the diagnostics fields.

<3.1> Subroutine FFT99 is called to do a 'half-complex' fast Fourier transform for each of the complete input grid point fields of the current scan. (See equation 5 of Section 2).

<3.11> For forecast data, the Fourier coefficients for the U-velocities have been generated from data which is staggered in the east-west direction. The corresponding 'unstaggered' coefficients are calculated using

$$U_m^u = e^{-\frac{im\Delta\lambda}{2}} U_m^S$$

where $\Delta\lambda = \frac{2\pi}{NLON}$

U_m^u = unstaggered n^{th} coefficient (complex)

U_m^S = staggered n^{th} coefficient (complex)

<3.2> Subroutine SYMASY is called to calculate the symmetric and antisymmetric parts of the Fourier fields (see equation 6 of Section 2). The Fourier coefficients for each field occupy NOREC rows of length NLP2, but space is available for NOREC+1 rows. If NPE = NOREC/2+1, then the symmetric parts of the fields are stored over rows 1 to NPE, and the antisymmetric parts over rows NOREC+1 to NPE+1. For forecast model data, v is given on rows staggered in the north-south direction, so that one row less of data is available. The symmetric parts of the V field are stored over rows 1 to NPE-1, and the antisymmetric parts are stored over rows NOREC+1 to NPE+2.

<4.1> Subroutine SHCOEF is called to calculate the spherical harmonic coefficients for scalar fields (see equation 18 of Section 2). If velocity fields are to be fitted, SHCOEF calculates the divergence and vorticity coefficients (see equations 23 and 24 of Section 2).

The functions $Z_{mn}(\phi_j^T), Z_{mn}^{I}(\phi_j^u), Z_{mn}^{II}(\phi_j^u), Z_{mn}^{I}(\phi_j^v), Z_{mn}^{II}(\phi_j^v)$

where ϕ_j^T = latitude of T grid points

ϕ_j^u = latitude of u grid points

ϕ_j^v = latitude of v grid points

are read from unit NZFILE. For each value of m, n, there is a record containing the 5 functions defined at latitudes from the pole to the equator. The functions are given in the order for the summation

$$\sum_{k=o}^{NTIN} \sum_{m=o}^{NTIN-k} Z_{m,m+k}$$ where NTIN is the triangular

truncation used to fit the spherical harmonics.

NB In the earlier versions of the package, the functions were held in the order

$$\sum_{m=o}^{NTIN} \sum_{n=m}^{NTIN} Z_{mn}$$

The output coefficient files are still held in this order, so that old programs which used them before the change still work. However, it was found that the spherical harmonic to grid point transformation could be vectorised if the new order were used. So the coefficients are calculated in the new order, and swapped round before being written to the output file.

<4.2> If velocity fields are being fitted with spherical harmonics subroutine UVCOEF is called to calculate the u and v coefficients from the divergence and vorticity coefficients. (See equations 29 and 30 of Section 2).

<5.1> Subroutine SHTOLL is called to extract the fields on the output grid, and write them to unit NGPOUT. It is described more fully in Section 7.2

<6> Find out which fields are to be processed in the next scan. Call REPOS to reposition the work file (or 4 work files) at the first data row.

<6.1> If NOLV = 0, i.e. there is insufficient space to process all the fields at a single level simultaneously, process the next set of scalar or velocity fields at the current level.

<6.2> If NOLV > 0 and all the levels in the current group have not yet been processed, do the next set of NOLV levels. If NOLV = 0 and all the fields at the current level have been processed, do the first set of NSC scalar fields at the next level.

<6.3> If all NPLEV levels of the current group of fields have been processed, start to do the next group of fields.

<7.1> If all the fields to be fitted by spherical harmonics have been processed, do the uninterpolated fields, in batches of N2D1 fields at a time. Subroutine OUT2D is called to write the uninterpolated fields to unit N2DOUT.

<7.3> If all the uninterpolated fields have been processed, subroutine OUTDIA is called to write the diagnostics fields to unit NDIOUT. They are processed in groups of NDISCN fields at a time.

7.2 Subroutine SHTOLL

If NLATO is non-zero, subroutine SHTOLL uses the spherical harmonics to calculate fields on the regular unstaggered latitude/longitude output grid. If NLATO=0, no output grid point fields are derived.

<2.1> For each latitude row of the output grid, the Legendre functions $P_{mn}(\phi)$ are read from unit NNLEG. There is one record for each row, ordered from north to south, and the Legendre functions are stored in the order corresponding to the summation

$$\sum_{k=o}^{NTIN} \sum_{m=o}^{\min(NTIN, NTIN+1-k)} P_{m,m+k}$$

<2.15>Subroutine POLARV is called to calculate the Fourier coefficients of the velocities at the poles, using equation 33 of Section 2.

<2.2> For all fields except velocities, equation 8 of Section 2 is used to calculate the Fourier coefficients at each latitude of the output grid.

<2.3> The Fourier coefficients of the velocity fields are calculated, using equation 30 of Section 2.

<2.6> Subroutine FFT99 is called to perform an inverse Fourier transform and extract the entire field on the output grid.

<2.7> The velocity fields extracted by this process have been $U = u\cos(\phi)$ or $V = v\cos(\phi)$. u or v can be calculated by dividing the appropriate field by $\cos(\phi)$.

<3.1> Subroutine OUTSHG is called to pack the field on the output grid, and write it to unit NGPOUT, in the format described by Section 9.

<3.2> If spherical harmonic coefficients are to be sent to the Cyber, subroutine OUTSHC is called to write them, in the format described by Section 9 to unit NSHOUT.

8. <u>Space control for the second part of the post-processing package</u>

Knowing NSPACE, the length of blank common available as work space, the number of fields which may be fitted with spherical harmonics in a single scan is calculated in subroutine SPANAL. On the input work file, the data is held in line form, but to fit spherical harmonics to a field, it must be converted to field form (i.e.all the rows must be held in core).

The input latitude/longitude grid has dimensions

NLP2 (number of longitude points + 2)

NOREC (number of latitude rows)

Space for an extra row of data is needed during the calculations, so that the input grid point field needs space NLP2*(NOREC+1).

If spherical harmonics are to be fitted with triangular truncation NTIN, then the spherical harmonic coefficients need space (NTIN+1)*(NTIN+2)

If the output grid has dimensions

NLONO (number of longitude points)

NLATO (number of latitude rows)

then the output grid point field needs space (NLONO+2)*NLATO.

To fit velocity fields with spherical harmonics, both u and v must be held on the input grid, and the spherical harmonics for divergence, D, and vorticity ζ , must be stored, as well as those for u and v. The divergence and vorticity spherical harmonic coefficients each need space (NTIN+1)*(NTIN+2), while the u and v coefficients each need space (NTIN+1)*(NTIN+4).

If there are NSCAL scalar fields and NVEL velocity fields at each level, the program calculates NOLV, the number of levels of data which may be processed in a single scan.

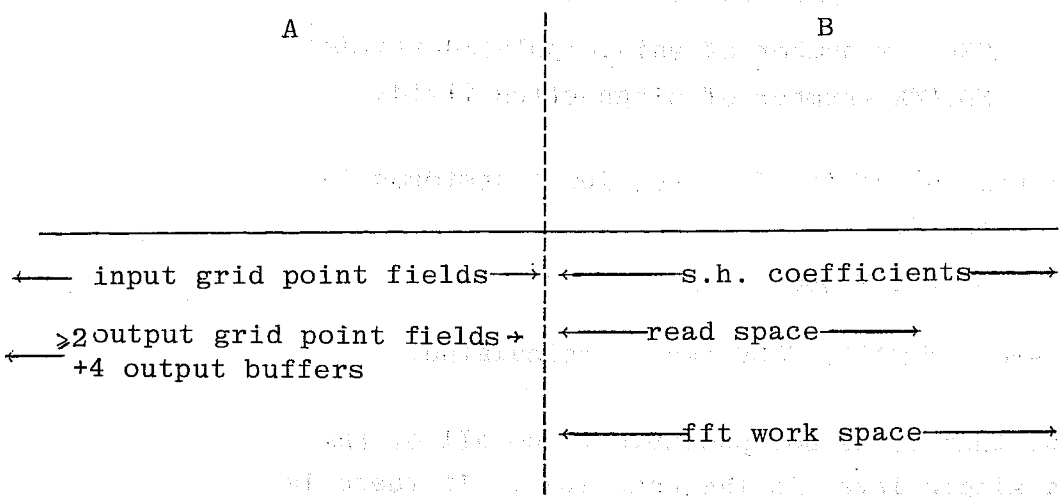

Fig. 8.1

Fig. 8.1 shows how various fields share the work space. Section A has the length of the maximum of:-

(i) space needed by NOLV*(NSCAL+NVEL) input grid point fields = NOLV*(NSCAL+NVEL)*NLP2*(NOREC+1)

(ii) space needed by 1 output grid point field + the workspace for the fast Fourier transform
+ space needed for 2 buffers each for packed output gridpoint and coefficient fields
= 2*NLATO*(NLONO+2) + NLATO*NLONO/2 +
MPRELO/2 + 2*((NTOUT+1)*(NTOUT+4)/3+MPRELO/3)

Section B has the length of the maximum of:-

(i) space needed by the spherical harmonic coefficients for NOLV*NSCAL scalar fields and NOLV*NVEL velocity fields
= NOLV*SCAL*(NTIN+1)*(NTIN+2)
+ NOLV*NVEL*((NTIN+1)*(NTIN+2)+(NTIN+1)*
(NTIN+4))

(ii) space to read in 2 lines of data
= NLP2*(MFDIN+N2D+NDIAWK)*2

where MFDIN = number of fields to be fitted with spherical harmonics

N2D = number of uninterpolated fields

NDIAWK =number of diagnostics fields

(iii) work space for fast Fourier transforms for input data

= NLP2*NOREC

Given that A+B $\leqslant$ NSPACE, NOLV can be calculated.

If NOLV = 0, then it is not possible to do all of the fields at a single level in the same scan. If there is insufficient space to do all the velocities at a single level in the same scan, the program terminates with an error message. Otherwise NSC, the number of scalar fields at a single level which can be done in a single scan, is calculated. Then for the first level, all the scalar fields are processed, with NSC (or a remainder < NSC) per scan, followed by a scan for the velocity fields (if there are any).This is repeated for the second and subsequent levels.

If NOLV $\geqslant$ NPLEV, the total number of levels to be processed, there is a test to see if there is sufficient space to also process all of the uninterpolated fields in the same scan. If so, they are built up beyond the longest of B(i) and B(ii). Otherwise the uninterpolated fields are done after all the fields to be fitted by spherical harmonics have been processed. Each field needs space of length NLP2*NOREC, and the number which can be processed in each scan is calculated and held in N2D1.

If NOLV≥NPLEV and all the uninterpolated fields can be fitted into a single scan, there is a further test to see if all the diagnostics fields can also be done on the same scan. Otherwise the diagnostics fields are processed at the end. Each field needs space of length NDIAWK*NOREC, and NDISCN diagnostics fields can be processed in a scan.

9. Format of the output files

Four different types of output file may be produced by the post-processing package:-

a) fields interpolated using spherical harmonics to a regular unstaggered latitude/longitude grid, written to unit FT17

b) spherical harmonic coefficients, on unit FT18

c) uninterpolated fields on the model grid, on unit FT19

d) diagnostics fields, on unit FT64

Each file has 3 data description records, followed by a data record for each field. The data description records are converted from Cray to Cyber format, but not packed before being written out. The first 2 data description records are the same for all 4 file types. The first record is the common block COMHKP, described in Section 10.1, which contains information describing the initial model or analysis data - its horizontal grid, vertical structure, date and time, etc. The second data description record is the common block COMSDO, described in Section 10.2. If the post-processing package was called during a forecast model run, then COMSDO contains parameters describing the model options selected for the particular run - such as the time step, the physics version or the tuning parameters. If the stand-alone version of the first part of the package was used, then COMSDO contains default values. The third data description record is different for each of the 4 file types. It contains sufficient information to describe the fields output, their horizontal grids, vertical levels and any parameters used for interpolation.

For file type (a), the third data descriptor record contains words 1→406 and 409→415 of common block COMSHH, described in Section 10.4. For file type (b), the third data descriptor record contains words 1→408 of common block COMSHH. For file type (c), the third data descriptor record is common block COMGPH, described in Section 10.3. For file type (d), the third data descriptor record is words 1-415 of common block COMDIA, described in Section 10.8.

Each data record contains a field of data, preceded by a preliminary array. The entire data record, including the preliminary array, is packed. Spectral coefficients of geopotential, in file type (b), are packed with 3 20-bit integers per word. All other spectral fields, and all fields for the other 3 file types, are packed with 4 15-bit integers per word. The preliminary array is the common block COMHDO, see Section 10.7. For grid point data on files of type (a) and (c), the data is ordered in rows from north to south, and from west to east within the rows. The rows of data are unwrapped, i.e. they do not have extra points before the first longitude point, or after the last point.

For file type (b), and triangular truncation NTOUT, the coefficients

$$\sum_{m=0}^{NTOUT} \sum_{n=m}^{\alpha} (\psi_{mn}^{real} + \psi_{mn}^{imaginary})$$

(where α = NTOUT for all fields except velocities

α = NTOUT+1 for velocity fields)

are stored in the order

$$\psi_{00}^{I},\ \psi_{01}^{R},\ \psi_{01}^{I},\ \psi_{02}^{R},\ \psi_{02}^{I},\ldots\ \psi_{0\alpha}^{R},\psi_{0\alpha}^{I},\ \psi_{11}^{R},\ \psi_{11}^{I},\ldots\psi_{1\alpha}^{R},\ \psi_{1\alpha}^{I},\ldots$$

$$\psi_{NTOUT,\alpha}^{R},\ \psi_{NTOUT,\alpha}^{I}$$

ψ_{00}^{R}, which represents the mean value of the field, is stored in the preliminary array, for reasons concerning the accuracy of the packing method, described below.

9.1 Packing routines

(i) Subroutine MAXMING searches all the values of a data field for the maximum (ZMAX) and minimum (ZMIN) values.

(ii) For all fields except spectral coefficients of geopotential, subroutine CODEREA is called to store ZMIN as 3 15-bit integers in words 9, 10 and 11 of the prelimary array (see Section 10). The algorithm used is

$$ZMIN = (K1*2^{15} + K2)*(10** \text{ AND } (K3,17777B))$$

where K1, K2 and K3 are words 9, 10 and 11 respectively. The sign of ZMIN is held in bit 15 of K3, and the sign of the exponent is held in bit 14 of K3. For spectral coefficients of geopotential, subroutine CODER3 is called to store ZMIN as 3 20-bit integers, using the algorithm

$$ZMIN = (K1*2^{20} + K2)*(10** \text{ AND } (K3,777777B))$$

(iii) The scaling factor, ZSCAL, is calculated where S = (U-ZMIN)*ZSCAL with S = scaled integer
U = unscaled real data element

Let IP be the number of bits used to pack each integer (i.e. IP=15 for all fields except spectral coefficients of geopotential, when IP=20).

If negative numbers could be packed, the method would be

$$IN = INT(Log_2\ (ZMAX-ZMIN) + \varepsilon)$$

where ε = machine precision

$$ZSCAL = 2^{(IP-1-IN)}$$

giving

$$S = \frac{(U-ZMIN)2^{IP-1}}{2^{IN}}$$

so $S<2^{IP}$, since $\frac{(U-ZMIN)}{2^{IN}}<2$

To keep IN (the integer stored in word 12 of the preliminary array) positive, the equations are shifted:-

$$IN = INT(Log_2(ZMAX-ZMIN) + \varepsilon + IBIAS)$$

where

$$IBIAS = 2^{IP-1} + 1$$

so $ZSCAL = 2^{(IBIAS+IP-1-IN)}$

and $-2^{IP-1} - 1 \leqslant Log_2(ZMAX-ZMIN) < 2^{IP-1} -1$

giving

$$0 \leqslant S < 2^{IP}$$

(iv) For all fields except spectral coefficients of geopotential, subroutine IPACK4 is called, to pack the preliminary array and the data record, with the lowest 15 bits of 4 positive Cray integers packed into the lowest 60 bits of each Cray word. (It is because the preliminary array is packed, with each word to be represented by a 15-bit integer that levels are held in the non-standard units of pascals/10. 15 bits is not usually sufficient to represent low-level pressures in pascals).

For spectral coefficients of geopotential, subroutine IPACK3 is called to pack the preliminary array and the data record, with the lowest 20 bits of 3 Cray positive integers packed into the lowest 60 bits of each Cray word. The packed preliminary array occupies words 1 to 5, and the first third of word 6. The packed data begins in word 7.

For packing spherical harmonic coefficients, the real (m=o,n=o) coefficient, which represents the mean value of the field, may be much larger than the other coefficients. By finding the values of ZMIN and ZSCAL for all coefficients except the real (m=o, n=o) coefficient, their variation can be more accurately represented. Subroutines CODEREA or CODER3 (see (ii) above) are called to store the real (m=o, n=o) coefficient in words 13, 14 and 15 of the preliminary array.

NB For files produced directly by the post-processing package, the preliminary array is packed, as described above. However, the retrieval programs which extract data from the operational data banks or operational archives return the data with unpacked preliminary arrays.

10. Common blocks

10.1 COMHKP - input data parameters

Word	Type	Name	Meaning	Where defined	Initial value	Where redefined	New value
1	I	NSIZDD	length of first data descriptor record, in words	DATCOM or OUTPAC or DDANAL	925	-	-
2	I	NPRELD	length of preliminary array, in words	"	24	-	-
3	I	NSZDD2	length of next data description record	"	500	HACNTL	35
4	I	MAXSIZ	length of maximum data record size	"	input grid dependent	OUT2D,OUTSHC OUTSHG	output grid dependent
5	I	NFRECD	record number of first data record	"	2	HACNTL	4
6	I	NCRDAT	creation date of output files	"	data dependent	HACNTL	actual date
7	I	NCRTIM	creation time of output files	"	"	HACNTL	actual time
8	I	NDTYPE	data type	"	1	OUT2D,OUTSHC, OUTSHG,OUTDTA	2 for grid point fields 11 for spherical harmonic coefficients if geopotential is packed 3 values/word 12 for spherical harmonic coefficients if geopotential is packed 4 values/word 13 for diagnostics
9	I	NOREC	number of latitude rows of input grid	"	grid dependent	-	-

Word	Type	Name	Meaning	Where defined	Initial value	Where redefined	New value
10	I	NTIMST	number of seconds/ common time unit (ctu)	DATCOM or OUTPAC or DDANAL	data dependent	INISTP, DATCOM	INT((TWODT+0.5)/2)
11	I	NCDATA	date of data on output file	"	"	DATCOM, SITOPR, HACNTL	format YYMMDD
12	I	NTDATA	time of data on output file (ctu's from midnight)	"	"	DATCOM, SITOPR	
13	I	NCBASE	data of initial fore-cast or analysis data	"	"	HACNTL	format YYMMDD
14	I	NTBASE	time of initial fore-cast or analysis data (ctu's from midnight)	"	"	-	-
15	R	ANORTH	north-west latitude of input grid (degrees)	"	"	-	-
16	R	WEST	north-west longitude of input grid	"	"	-	-
17	R	SOUTH	south-east latitude of input grid	"	"	-	-
18	R	EAST	south-east longitude of input grid	"	"	-	-
19	R	GRIDEG	east-west resolution of input grid (degrees)	"	"	-	-

Word	Type	Name	Meaning	Where defined	Initial value	Where redefined	New value
20	I	NLP2	number of longitude points +2 of input data	DATCOM or OUTPAC or DDANAL	data dependent	-	-
21	I	NVECT	number of fields in input data file	"	"	-	-
22	I	NCHAR	location of character description section (word number)	"	25	-	-
23	I	NUSER	location of user area	"	725	-	-
24	I	NDDNUM	record number	"	1	-	-
25-724	H	CHARS(700)	character description of initial data	"	data dependent	-	-
725	I	ILEV	number of vertical model levels in following words	"	for a forecast model with NLEV σ-levels, and NLEV+1 intermediate levels, ILEV=2*NLEV+1. For an analysis file with NLEV pressure levels, ILEV=NLEV	-	-
726	I	IVTYPE	type of vertical coordinate system of initial data	"	forecast files - IVTYPE=2 (σ- levels) analysis files - IVTYPE=1 (pressure levels)	-	-
727	R	USER(3)	value of top level	"	$\sigma_{\frac{1}{2}}$ (forecast file) or P_1 (analysis file)	-	-
728	R	USER(4)	value of 2nd level	"	σ_1 or P_2	-	-
729	R	USER(5)	value of 3rd level	"	$\sigma_{1\frac{1}{2}}$ or P_3	-	-

Word	Type	Name	Meaning	Where defined	Initial value	Where redefined	New value
726+ ILEV	R	USER (2+ILEV)	value of lowest level	DATCOM or OUTPAC or DDANAL	$\sigma_{NLEV+\frac{1}{2}}$ or P_{NLEV}	-	-
727+ ILEV-NSIZDD			spare				

10.2 COMSDO - Second data descriptor record for output files

Word	Type	Name	Meaning	Where defined	Initial value	Where redefined	New value
1	I	MSZSDO	length of second data descriptor record, in words	PRESTP	34	-	-
2	I	MPRSDO	length of preliminary array	"	34	-	-
3	I	MNXSDO	length of next data descriptor record	"	413	OUT2D or OUTSHC or OUTSHG	45 or 413 or 418 depending on output file type
4	L	MLPHYS	switch for physics in model	"	depends on model run (false for stand-alone version)	-	-
5	L	MLSIMP	switch for semi-implicit scheme	"	"	-	-
6	L	MLVTMP	switch for virtual temperature	"	"	-	-
7	L	MLHEM	switch for hemispheric version	"	"	-	-
8	L	MLPHEC	switch for ECMWF physics	"	"	-	-
9	L	MLRDEC	switch for ECMWF radiation	"	"	-	-
10	L	MLKUO	switch for Kuo convection scheme	"	"	-	-
11	L	MLEVAR	switch for evaporation of rain	"	"	-	-

Word	Type	Name	Meaning	Where defined	Initial value	Where redefined	New value
12	L	MLNRAD	switch for radiation	PRESTP	depends on model run (false for stand-alone version)	-	-
13	L	MLCLD	switch for cloud parameterisation	"	"	-	-
14	L	MLDIUR	switch for diural variation	"	"	-	-
15	L	MLSDFM	switch for horizontal diffusion (type 1)	"	"	-	-
16	L	MLD2D4	switch for horizontal diffusion (type 2)	"	"	-	-
17	L	MLHDIF	switch for horizontal diffusion (type 3)	"	"	-	-
18	L	MLSPFL	space filter-filter dynamics tendencies only	"	"	-	-
19	L	MLSPCH	space filter-chop dynamics tendencies only	"	"	-	-
20	L	MLTFCH	space filter-total field chopping	"	"	-	-
21	L	MLTFFI	space filter-total field filtering	"	"	-	-

Word	Type	Name	Meaning	Where defined	Initial value	Where redefined	New value
22	L	MLTTCH	space filter-total tendency chopping	PRESTP	depends on model run (false for stand-alone version)	-	-
23	L	MLTTFI	space filter-total tendency filtering	"	"	-	-
24	I	MNRAD	frequency of radiation time steps	"	(0 for stand-alone version)	-	-
25	R	CTWODT	2*time step (seconds)	"	(0 for stand-alone version)	-	-
26	R	CEPS	time smoothing constant	"	"	-	-
27	R	CCTHO	cos(latitude boundary for space filter)	"	"	-	-
28	R	CCRITT	critical relative humidity for condensation scheme	"	"	-	-
29	R	CLASYM	mixing length parameter	"	depends on model run (0 for stand alone version)	-	-
30	R	CTPER	period for soil-heat transfer	"	"	-	-
31	R	CTDIF	diffusion coefficient for soil processes	"	"	-	-
32	R	CSSAT	soil-water saturation value	"	"	-	-
33	R	CZK	horizontal diffusion coefficient	"	"	-	-
34	I	MRCSDO	record number	"	"	-	-

10.3 COMGPH - 3rd data descriptor record for uninterpolated fields

Word	Type	Name	Meaning	Where defined	Initial value	Where redefined	New value
1	I	MSIZR2	length of data descriptor record	PRESTP	45	-	-
2	I	MSIZP2	length of preliminary array	"	45	-	-
3	I	MSIZD2	length of first data record	"	-(NLON*NOREC+MPRELO)	-	-
4	I	N2D	number of uninterpolated fields	"	0	INISTP	user defined
5-44	I	NGPCL (2,20)	NGPCL(1,J)=code*of J^{th} uninterpolated field NGPCL(2,J)=level of J^{th} uninterpolated field (either pascals/10 or - 100 (surface) or - 200 (mean sea level))	"	0,0	INISTP	user defined
45	I	MREC2D	record number	"	3	-	-

* SEE FIG. 3.5.1

10.4 COMSHH - 3rd data descriptor record for spherical harmonic coefficients or interpolated fields

Word	Type	Name	Meaning	Where defined	Initial value	Where redefined	New value
1	I	MSIZRS	length of data descriptor record	PRESTP	413	OUTSHC, OUTSHG	408 for s.h. coefficient file 413 for grid-point file
2	I	MSIZPS	length of preliminary array	"	413	OUTSHC, OUTSHG	408 or 413
3	I	MSIZDS	length of first data record	INISTP	-(NLONO*NLATO+MPRELO)	OUTSHC, OUTSHG	-((NTOUT+1)*(NTOUT+2)-1+MPRELO) or -((NTOUT+1)*(NTOUT+4)-1+MPRELO) or -(NLONO*NLATO+MPRELO)
4	I	MFDOUT	number of data fields on output file	REORDR	data dependent	-	-
5-404	I	NCL (2,200)	NCL(1,J)=code of J^{th} field NCL(2,J)=level of J^{th} field (in pascals/10), or model σ-level number, if NVINT=Ø	PRESTP	0,0	REORDR	data dependent
405	I	NVINT	vertical interpolation type (1=linear, 3=cubic spline Ø= no interpolation, fields on σ-levels)	"	3	INISTP	user defined
406	I	NTIN	triangular truncation of spherical harmonics used to fit data	"	0	INISTP	"
407	I	NTOUT	triangular truncation of spherical harmonic coefficients written to output file	"	0	"	user defined
408	I	MRECSC	record number for s-h coefficients output file	"	3	-	-
409	I	NLATO	number of latitude rows in output grid (NLATO=Ø if there are no output grid point fields).	"	NOREC	INISTP	user defined

Word	Type	Name	Meaning	Where defined	Initial value	Where redefined	New value
410	I	NLONO	number of longitude points in output grid	PRESTP	NLON	INISTP	user defined
411	R	GNLAT	latitude of north-west corner of output grid (degrees)	"	ANORTH	"	"
412	R	GWLON	longitude of north-west corner of output grid	"	WEST	"	"
413	R	GSLAT	latitude of south-east corner of output grid	"	SOUTH	"	"
414	R	GELON	longitude of south-east corner of output grid	"	EAST	"	"
415	I	MRECSG	record number for grid-point fields output file	"	3	-	-

10.5 COMSH1 - output package parameters

Word	Type	Name	Meaning	Where defined	Initial value	Where redefined	New value
1	I	NLNSH1	length of COMSH1	PRESTP	8716	-	-
2	I	NPOUT	unit number of work file	PRESET, OUTPAC	60 (forecast-called version) or KOUT (stand alone version)	HACNTL	
3	I	NZFILE	unit number of first spherical-harmonic constants file	"	15	-	-
4	I	NNLEG	unit number of file containing Legendre functions at output grid latitudes	"	16	-	-
5	I	NGPOUT	unit number of output file containing grid point fields interpolated using spherical harmoncs	"	17	-	-
6	I	NSHOUT	unit number of output file containing spherical harmonic coefficients	"	18	-	-
7	I	N2DOUT	unit number of output file con- containing uninterpolated fields	"	19	-	-
8	I	NPSTEP	forecast step at which output package is next to be called	PRESTP	-2	INISTP, LINEMS	NPWTIM(NPPTR)
9-208	I	NPWTIM (200)	all forecast steps at which output package is to be called	"	-2	INISTP	user defined
209	I	NPPTR	pointer to current element of NPWTIM	"	0	INISTP, LINEMS	NPPTR=NPPTR+1

Word	Type	Name	Meaning	Where defined	Initial value	Where redefined	New value
210	I	NPLEV	number of vertical levels in current group of fields	PRESTP	0	INISTP, SITOPR HACNTL	NMLV or 1
211	I	NPE	number of rows between pole and equator on input grid	SYMASY	NOREC/2+1	-	-
212	I	NSPACE	length of blank common available for work space	PRESTP	700 000	INISTP	user defined
213	I	NSTADD	start address in blank common of work space	"	1	"	"
214	I	NMFD	number of multi-level fields to be interpolated using spherical harmonics	"	0	"	"
215-224	I	NFDML (10)	codes of multi-level fields	"	0	"	"
225	I	NMLV	number of pressure levels at which multi-level fields are to be output	"	0	"	"
226-255	I	NLVML (30)	levels of multi-level fields (pascals/10); or model σ-level numbers if NVINT=Ø	"	0	"	"
2561	I	NSFD	number of single-level fields to be interpolated using spherical harmonics	"	0	"	"
257-286	I	NFDSL (30)	codes of single-level fields	"	0	"	"

Word	Type	Name	Meaning	Where defined	Initial value	Where redefined	New value
287–316	I	NLVSL (30)	levels of single-level fields (pascals/10); or model σ-level numbers if NVINT=Ø	PRESTP	0	INISTP	user defined
317–516	I	MHAIN (200)	codes of reordered fields on work file	REORDR	data dependent	-	-
517–716	I	MHAOUT (200)	codes of fields to be output	"	"	-	-
717	I	MFDIN	number of input fields to be interpolated using spherical harmonics	"	"	-	-
718–767	I	NPTAR (50)	control array describing groups of scalar and velocity fields on work file	"	"	-	-
768–777	I	NFAXI (10)	constants for fft on input grid	HAFFT	grid dependent	-	-
778–787	I	NFAXO (10)	constants for fft on outptut grid	"	data dependent	-	-
788	L	NLANAL	true if initial data is an analysis file, false for forecast data	PRESET or OUTPAC	data dependent	-	-
789	L	NLSTAL	true for stand-alone version, false for forecast-called version	PRESET or OUTPAC	false (PRESET) or true (OUTPAC)	-	
790	L	NLINI	true for σ-level analysis files	PRESTP or OUTPAC	false	EXFAMD	depends on operational family name
791	R	DTHETA	latitudinal grid interval of input grid (radians)	INISTP	Π/(NOREC-1)	-	-
792	R	DLATO	latitudinal grid interval of output grid	"	Π/(NLATO-1)		

Word	Type	Name	Meaning	Where defined	Initial value	Where redefined	New value
793-4194	R	DD(3402)	constants used in spherical harmonic interpolation	MAKEDS	$DD_{mn} = -\left(\frac{n^2-m^2}{4n^2-1}\right)^{\frac{1}{2}} \cdot \frac{1}{n}$	-	-
4195-7596	R	SS(3402)	constants used in spherical harmonic interpolation	"	$SS_{mn} = -\frac{m}{n(n+1)}$	-	-
7577-7956	R	TRIGSI (360)	constants for fft on input grid	HAFFT	grid dependent	-	-
7957-8316	R	TRIGSO (360)	constants for fft on output grid	"	"	-	-
8317-8716	I	NCLIN (2,200)	NCLIN(1,J)=code of J^{th} field on work file NCLIN(2,J)=level of J^{th} field on work file	REORDR	data dependent		

10.6 COMSH2 - output package parameters

Word	Type	Name	Meaning	Where defined	Initial value	Where redefined	New value
1	I	MLEVUP	level number of first level in current scan	HACNTL	1	HACNTL	MLEVUP+NOLV or MLEVUP+1 or 1
2	I	MNOLV	actual number of levels processed in current scan	HACNTL	data dependent	-	-
3	I	NOLV	maximum number of levels which could be processed in current scan	SPANAL	space dependent	-	-
4	I	NF	number of fields at each level which can be processed in current scan	SPANAL	NSCAL+NVEL	HACNTL	data dependent
5	I	NF1	first field to be processed at each level in current scan	SPANAL	NFSH	HACNTL	"
6	I	NSC	maximum number of scalar fields which can be processed in current scan	SPANAL	space dependent	-	-
7	I	NSCAL	number of scalar fields at each level in current group	REORDR, HACNTL	data dependent	-	-
8	I	NVEL	number of velocity fields on work file at each level in current group	REORDR, HACNTL	data dependent	-	-
9	I	NVELO	number of velocity fields to be written to output file at each level of current group	REORDR, HACNTL	data dependent	-	-

Word	Type	Name	Meaning	Where defined	Initial value	Where redefined	New value
10	I	NTY	type of scan (1=all fields at each level, 2=scalar fields at current level, 3=velocity fields at current level)	SPANAL	space dependent	HACNTL	data dependent
11	I	NLENG	(complex) length of a field of data on the input grid	DISINI	NLP2*(NOREC+1)/2	-	-
12	I	NLENHS	(complex) length of a field of scalar spherical harmonic coefficients	"	(NTIN+1)*(NTIN+2)/2	-	-
13	I	NLENHV	(complex) length of a field of velocity spherical harmonic coefficients	"	(NTIN+1)*(NTIN+4)/2	-	-
14	I	NHAST	start address of spherical harmonic coefficient space in (complex) blank common	"	data dependent	-	-
15	I	NRSP	space required to read a work file record	SPANAL	NLP2*(MFDIN+N2D)	-	-
16-115	I	NDISGR (100)	(complex) displacement in blank common of each grid point field to be processed in current scan	DISINI	data dependent	-	-
116-215	I	NDISSH (100)	(complex) displacement in blank common of each field of s.h. coefficients to be processed in current scan	"	"	-	-
216	I	NPASS	number of group of fields currently being processed	HACNTL	1	HACNTL	NPASS=NPASS+1 or NPASS=0

Word	Type	Name	Meaning	Where defined	Initial value	Where redefined	New value
217	I	N2DST	control parameter for handling uninterpolated fields (0=no uninterpolated fields; 1=uninterpolated fields to be done at a later stage, 2=uninterpolated fields currently being processed)	HACNTL	data dependent	HACNTL	data dependent
218	I	NR2D	no longer used				
219	I	NDIS2D	start address in blank common of uninterpolated fields	DISINI	data dependent	-	-
220	I	NFSH	element of MHAIN containing first input field of current group	HACNTL	1	HACNTL	NFSH=NFSH+NSCAL+NVEL
221	I	N2D1	number of uninterpolated fields being processed in current scan	SPANAL	space dependent	HACNTL	data dependent
222	I	NFOSH	element of MHAOUT containing first output field of current group	HACNTL	1	HACNTL	NFOSH=NFOSH+NSCAL+NVELO
223	I	NF2D	first uninterpolated field to be processed in current scan	HACNTL	1	HACNTL	NF2D=NF2D+N2D1

10.7 COMHDO - preliminary array for data records on output files

Word	Type	Name	Meaning	Where defined	Initial value	Where redefined	New value
1	I	MSIZDO	total (unpacked) data record length	PRESTP	MPRELO+NLON+NOREC	OUT2D, OUTSHC, OUTSHG or OUTDIA or	MPRELO+NLON*NOREC or MPRELO+(NTOUT+1)*(NTOUT+2)-1 MPRELO+(NTOUT+1)*(NTOUT+4)-1 MPRELO+NLONO*NOREC MPRELO+NDIAWK*NOREC
2	I	MPRELO	length of preliminary array	"	16	-	-
3	I	MNXDO	length of next data record	"	MSIZDO	OUT2D, OUTSHC, OUTSHG OUTDIA	data dependent
4	I	MX1DO	maximum subscript of first dimension	"	NLON	OUT2D, OUTSHC, OUTSHG OUTDIA	NLON or NTOUT+1 or NTOUT+2 or NLONO or NDIAWK
5	I	MX2DO	maximum subscript of second dimension	"	NOREC	OUT2D, OUTSHC, OUTSHG OUTDIA	NOREC or NTOUT+1 or NLATO or NOREC
6	I	MTYDO	data type (1=uninterpolated fields, 2=grid point fields interpolated using spherical harmonics, 3=spherical harmonic coefficients,4=diagnostics, 5=spherical harmonic coefficients packed 3 values/word)	"	2	OUT2D, OUTSHC, OUTSHG OUTDIA	1, 3, 5, 2 or 4
7	I	MFDO	code of field output in this record	"	0	OUT2D, OUTSHC, OUTSHG OUTDIA	field dependent
8	I	MLEVO	level of field output in this record	"	0	OUT2D, OUTSHC, OUTSHG OUTDIA	level dependent

Word	Type	Name	Meaning	Where defined	Initial value	Where redefined	New value
9	I	MZM1	minimum value of field,	PRESTP	0	OUT2D, OUTSHC, OUTSHG OUTDIA	data dependent
10	I	MZM2	stored by method described				
11	I	MZM3	in Section 9.1				
12	I	MINO	scaling factor for packing routines				
13	I	MSHOO1	real (m=o,n=o) spherical	"	0	OUT2D, OUTSHC, OUTSHG OUTDIA	data dependent, or 0
14	I	MSHOO2	harmonic coefficient,				
15	I	MSHOO3	stored by method described in Section 9.1 [undefined for grid point fields]				
16	I	MRECDO	record number	"	4	OUT2D, OUTSHC, OUTSHG OUTDIA	

10.8 COMDIA - diagnostics constants

Word	Type	Name	Meaning	Where defined	Initial value	Where redefined	New value
1	I	MSZDIA	Length of data descriptor record	PRESTP	415	-	-
2	I	MPRDIA	Length of preliminary array	"	415	-	-
3	I	MNXDIA	Length of first data record	"	-(NLEV*MAXROW+ MPRELO)	-	-
4	I	NDIFDS	number of non-zero diagnostics fields written to output file	"	48	OUTDIA	data dependent
5	I	NDIMAX	number of input diagnostics fields	"	48	-	-
6-293	I	MDIACD(6,48)	6 codes for each group of diagnostics fields	"	Ø	HACNTL	data dependent
294-414	I	MLAND(121)	number of land points in J^{th} latitude row	"	Ø	-	-
415	I	MRCDIA	record number	"	3	-	-
416	I	NDIAST	control parameter for handling diagnostic fields (Ø=no diagnostic fields 1=diagnostic fields to be done later 2=diagnostic fields to be processed on this scan)	"	Ø	HACNTL	data dependent
417		MCDIN	diagnostic code	REORDR	23	-	-
418	I	NDIAWK	length of diagnostic data in work file = NDIAWK*NLP2	PRESTP	Ø	REORDR	NLEV
419	I	NDIOUT	unit number for output diagnostic file	"	64	-	-
420	I	NFDIA	first diagnostic field to be processed in current scan	HACNTL	1	HACNTL	NFDIA=NFDIA+NDISCN
421	I	NDISCN	number of diagnostic fields being processed in current scan	SPANAL	space dendent	HACNTL	data dependent
422	I	NDISDI	start address in block common of diagnostic fields	DISINI	data dependent	-	-

11. Sample programs

Three sample programs are given. Fig. 11.1 is an example of the forecast-called version of the first part of the output package. Fig. 11.2 shows the stand-alone version of the first part of the package taking as input an analysis file. Fig. 11.3 is an example of the second part of the post-processing package.

References

Machenhauer, B. and Daley, R.	1972	"A baroclinic primitive equation model with a spectral representation in 3-dimensions"
Haseler, J. and Burridge, D.	1977	"Documentation for the ECMWF grid point mode" ECMWF Internal Report No.9

POSTIN - namelist input to post-processing

Name	Meaning	Default
ILPOST	.TRUE. for post processing	.FALSE.
NLATO	number of latitude rows in output grid (if NLATO=0, no output grid point fields will be produced)	NOREC
NLONO	number of longitude points in output grid	NLON
GNLAT	latitude (degrees) of northern boundary of output grid	ANORTH
GWLON	longitude (degrees) of western boundary of output grid	WEST
GSLAT	latitude of southern boundary of output grid	SOUTH
GELON	longitude of eastern boundary of output grid	EAST
NTIN	triangular truncation of grid point to spherical harmonic transformation	Ø
NTOUT	truncation of spherical harmonics coefficient to be output	Ø
NVINT	vertical interpolation type (1=linear, 3=spline. If NVINT=Ø, fields are not interpolated vertically but are left on σ-levels)	3
NPWTIM(200)	Post-processing step numbers (J^{th} post-processing is at step NPWTIM(J)	200*-2
NSPACE	work space available for second part of post-processing package (in words)	700 000
NSTADD	start address in blank common of work space for second part of output package	1
NMFD	number of fields at multiple levels	Ø
NFDML(10)	codes for multi-level fields	10*0
NMLV	number of levels for multi-level fields	0
NLVML(30)	levels for multi-level fields (units=pascals/10), or model σ-level numbers if NVINT=0	30*0
NSFD	number of single level fields	0
NFDSL(30)	codes for single level fields	30*0
NLVSL(30)	levels for single level fields (units=pascals/10), or model σ-level numbers if NVINT=0	30*0
N2D	number of uninterpolated fields	0
NGPCL(2,20)	J^{th} uninterpolated field has code NGPCL(1,J) and level NGPCL(2,J), with the level in units=pascals/10. or -100 for surface fields, or -200 for fields at mean sea level.	40*0
NLCALC	If NLCALC = .TRUE., calculate spherical harmonic constant files.	.FALSE.

FIG. 3.1

Fields available for post-processing

Code	Field	Input field type (F=forecast or analysis σ-file A=analysis pressure file)	Post-processing type (s=field fitted by spherical harmonics) u=uninterpolated field)
1	geopotential	F,[A-surface geopotential only]	s,[u-surface geopotential only]
2	temperature	F,A	s
3	u-velocity	F,A	s, u-surface velocity, analysis only
4	v-velocity	F,A	s, u-surface velocity, analysis only
5	humidity mixing ratio	F	s
6	pressure	F,A	s - mean sea level pressure u - surface pressure
7	vertical velocity	F	s
8	-		
9	precipitable water content	F,A	s
10	vorticity	F,A	s
11	surface temperature	F,A	u
12	soil wetness	F	u
13	snow depth	F	u
14	large scale rain	F	u
15	convective rain	F	u
16	snow fall	F	u
17	boundary layer dissipation	F	u
18	surface sensible heat flux	F	u
19	surface latent heat flux	F	u
20	surface stress	F	u
21	surface net radiation	F	u
22	net radiation at top	F	u
23	diagnostics	F	u
24	-		

FIG. 3.5.1

Code	Field	Input field type (F=forecast or analysis σ-file A=analysis pressure file)	Post-processing type (s=field fitted by spherical harmonics u=uninterpolated field)
25	u-velocity gridpoint field, vorticity spectral field	F,A	s
26	v-velocity gridpoint field, divergence spectral field	F,A	s
27	divergence	F,A	s
28	height	A	s
29	relative humidity	F,A	s
30	surface pressure tendency	F	s,u
31	u-errors	A	s
32	v-errors	A	s
33	geopotential errors	A	s
34	thickness errors	A	s
35	precipitable water content errors	A	s
36	cloud cover	F	u
37	u at 10 metres	F	u
38	v at 10 metres	F	u
39	temperature at 2 metres	F	u
40	dew point temperature at 2 metres	F	u

FIG. 3.5.1 continued

```
NAJAN,T500,STCRA,CM500.                                      Post-processing launched from forecast
ACCOUNT,ECRMGG.
ASSIGN,DN=FT10,DV=DD-19-20,BS=22.                         }
ASSIGN,DN=FT11,DV=DD-19-32,BS=22.                         }  forecast work files
ASSIGN,DN=FT12,DV=DD-19-40,BS=22.                         }
ASSIGN,DN=FT13,DV=DD-19-52,BS=22.                         }
ASSIGN,DN=FT24,DV=DD-19-41.
ASSIGN,DN=FT25,DV=DD-19-33.
ASSIGN,DN=FT27,DV=DD-19-21.
ACQUIRE,DN=FT30,PDN=N48SDS,ID=NAJ,DF=TR,UQ.                  Start data set
CFT.
ACCESS,DN=FT20,PDN=AINI800922000,ID=OI000.                   forecast initial data
ACQUIRE,DN=N48,PDN=N48CRAYOBJ,ID=EWP3,DF=TR.
ACQUIRE,DN=CLIB,PDN=N48CALOBJ,ID=EWP3,DF=TR,MF=CY.
LDR,LIB=N48:ECLIB:NAGLIB,DN=CLIB:$BLD,T=P,MAP.
SAVE,DN=FT60,PDN=P60,ID=NAJ.                              }
SAVE,DN=FT61,PDN=P61,ID=NAJ.                              }  post-processing work files
SAVE,DN=FT62,PDN=P62,ID=NAJ.                              }
SAVE,DN=FT63,PDN=P63,ID=NAJ.                              }
(EOR)
      PROGRAM P
      COMMON B(300000)
      CALL MASTER
      STOP
(EOR) END
OPERATIONAL GRID POINT MODEL                              }
J6 DYNAMICS - SEMI IMPLICIT                               }  label cards for forecast run
E.C.M.W.F. PHYSICS                                        }
E.C.M.W.F. RADIATION                                      }
 $NEWRUN
 $END                                                        take default forecast variables
 $POSTIN
      ILPOST=.T.,NTIN=80,NTOUT=40,NPWTIM(1)=5,               input data for post-processing
      NMFD=4,NFDML=1,3,4,29,NMLV=2,NLVML=5000,10000,
      NSFD=1,NFDSL=6,NLVSL=-200,
      N2D=5,NGPCL=11,-100,12,-100,13,-100,14,-100,23,-100,
 $END
```

FIG. 11.1

```
NAJAN,STCRA,CM500,T20.                              stand-alone post processing on analysis pressure-level
                                                                                                     file
ACCOUNT,ECRMGG.
CFT.
ACCESS,DN=FT20,PDN=APPF800922000,ID=DA000.          input analysis file
ACQUIRE,DN=N48,PDN=N48CRAYOBJ,ID=EWP3,DF=TR.
ACQUIRE,DN=CAL,PDN=N48CALOBJ,ID=EWP3,DF=TR.
LDR,LIB=N48:ECLIB:NAGLIB,DN=$BLD:CAL.
SAVE,DN=FT60,PDN=P60,ID=NAJ.
SAVE,DN=FT61,PDN=P61,ID=NAJ.                        } post processing work files
SAVE,DN=FT62,PDN=P62,ID=NAJ.
SAVE,DN=FT63,PDN=P63,ID=NAJ.
(EOR)
      PROGRAM GPMODEL
      COMMON B(700000)
      CALL OUTPAC(20,60,5,6)
      STOP
(EOR) END
       F        1                                   F for pressure file (T for sigma file)
 $POSTIN                                            1 for single input file
      ILPOST=.T.,NTIN=80,NTOUT=80,
      NMFD=3,NFDML(1)=3,4,28,
      NMLV=2,NLVML=5000,10000,                      input data for post-processing
      N2D=3,NGPCL=6,-100,6,-200,11,-100,
 $END


***********         NAJPSD5  //// END OF LIST ////
***********         NAJPSD5  //// END OF LIST ////
```

FIG. 11.2

```
NAJAN,CM500,STCRA,T20.                                                  second part of post-processing
ACCOUNT,ECRMGG.
CFT.
ACQUIRE,DN=FT15,PDN=RZZ80N60,ID=NAJ,DF=TR,^
  TEXT='VSN(T=1996F)LABEL(T,R,NORING,D=GE,L=RZZ80N60)'.                 constants files
ACQUIRE,DN=FT16,PDN=RLEG80N48,ID=NAJ,DF=TR,^
  TEXT='VSN(T=96R)LABEL(T,R,NORING,D=GE,L=RLEG80N48)'.
ACQUIRE,DN=OUT,PDN=N48CRAYOBJ,ID=EWP3,DF=TR.
ACQUIRE,DN=CAL,PDN=N48CALOBJ,ID=EWP3,DF=TR.
ACCESS,DN=FT60,PDN=P60,ID=NAJ.
ACCESS,DN=FT61,PDN=P61,ID=NAJ.
ACCESS,DN=FT62,PDN=P62,ID=NAJ.                                          post-processing work files
ACCESS,DN=FT63,PDN=P63,ID=NAJ.
LDR,LIB=OUT:ECLIB,DN=$BLD:CAL.
DISPOSE,DN=FT17,SDN=GRID,ID=NAJ,DC=ST,DF=BB.                            output grid point field
DISPOSE,DN=FT18,SDN=SHCOEFFS,ID=NAJ,DC=ST,DF=BB.                        output spherical harmonic coefficients
DISPOSE,DN=FT19,SDN=UNINTERP,ID=NAJ,DC=ST,DF=BB.                        output uninterpolated fields
DISPOSE,DN=FT64,SDN=DIAG,ID=NAJ,DC=ST,DF=BB.                            output diagnostics fields
(ecl)
      PROGRAM GPMODEL
      COMMON X(5),B(700000)
      CALL HACNTL
      STOP
      END
(ECL)
        60                      NPOUT                                   unit number of first post processing
                                                                        work file

***********          NAJPTD5   //// END OF LIST ////
***********          NAJPTD5   //// END OF LIST ////
```

FIG. 11.3