U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
NATIONAL METEOROLOGICAL CENTER

OFFICE NOTE 394

THE NMC ETA MODEL POST PROCESSOR: A DOCUMENTATION

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JUNE 1993

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1. Introduction

This Office Note describes the post processor for the National Meteorological Center Eta model. Preliminary to this discussion is a brief review of the Eta model emphasizing the model grid and arrangement of variables. A general overview of the post processor design, usage, and capabilities follows. Currently 110 unique fields are available from the post processor. The final section documents these fields and the algorithms used to compute them. Appendix 1 lists the various NMC data sets from which operational Eta model output is available. Details for using the post processor in conjunction with the model are found in Appendix 2.

The Eta post processor is not a stagnant piece of code. New output fields, improved algorithms, GRIB packing, and code optimization are just a few areas in which development continues. However, it is unlikely that the algorithms discussed in this Office Note will dramatically change.

2. The Eta Model

Since its introduction by Philips (1957) the terrain–following sigma coordinate has become the vertical coordinate of choice in most numerical weather prediction models. A prime reason for this is simplification of the lower boundary condition. Difficulties arise in the sigma coordinate when dealing with steep terrain. In such situations the noncancellation of errors in two terms of the pressure gradient force becomes significant (Smagorinsky *et al.*, 1967). These errors in turn generate advection and diffusion errors. Numerous methods have been devised to account for this defect of the sigma system. Mesinger (1984) took a different approach in defining the eta coordinate,

$$\eta = \frac{p - p_t}{p_s - p_t} \times \eta_s$$

where

$$\eta_s = \frac{p_{rf}(z_s) - p_t}{p_{rf}(0) - p_t}$$

In this notation p is pressure and subscripts rf, s, and t respectively refer to reference pressure, the model surface, and the model top ($p_t = 50$ mb). The height z is geometric height. Observe that the sigma coordinate appears as the $\eta_s = 1$ case of the eta coordinate. The reference pressure used in the Eta model is $p_{rf}(z) = p_{rf}(0)\left(\frac{T_0 - \Gamma z}{T_0}\right)^{\beta}$ where $p_{rf}(0) = 1013.25\text{mb}$, $T_0 = 288\text{K}$, $\Gamma = 6.5°/\text{km}$, $\beta = \frac{R\Gamma}{g}$, $g = 9.80\,{}^{\text{m}}/_{\text{s}^2}$, and $R = 287.04\,{}^{\text{J}}/_{\text{K-kg}}$.

In the eta coordinate terrain assumes a step–like appearance thereby minimizing problems associated with steeply sloping coordinate surfaces. At the same time the coordinate preserves the simplified lower boundary condition of a terrain following vertical coordinate.

The Eta model uses the semi–staggered Arakawa E grid (Fig. 1). Prognostic variables at mass (H) points are surface pressure, temperature, and specific humidity. Zonal and meridional wind components are carried at velocity (V) points. The E grid is mapped to a rotated latitude–longitude grid which is centered at 52N and 111W for the operational Eta. Two rotations are involved. One moves the Greenwich meridian to 111W. The second shifts the equator to 52N. Each row of the E grid lies along a line of constant rotated latitude; each column along a line of constant rotated longitude. In the operational Eta the shortest distance between like grid points is approximately 80 km. The large box in Fig. 1 delimits the extent of the computational domain. Prognostic variables on the outermost rows and columns are specified by a global model forecast from the previous cycle. The second outermost rows and columns serve to smoothly blend boundary conditions with values in the computational domain. The boundaries are one way interactive.

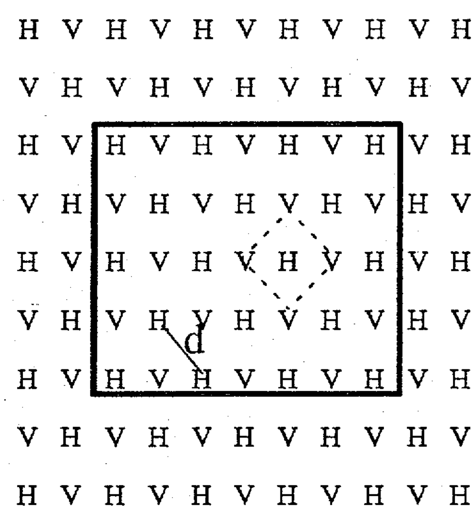

Fig. 1. Arakawa E grid of Eta model. H denotes mass points, V velocity points. The solid box outlines the computational domain. The distance d between like grid points is approximately 80 km. The dashed box represents a model step.

Model terrain is represented in terms of discrete steps. Each step is centered on a mass point with a velocity point at each vertex. This is suggested by the dashed box in Fig. 1. The algorithm creating the steps tends to maximize their heights (so–called silhouette topography) based on the raw surface elevation data. Topography over the operational Eta domain is discretized into steps from sea level to 3264 meters over the Colorado Rockies. Figure 2 represents these steps on a bar chart.

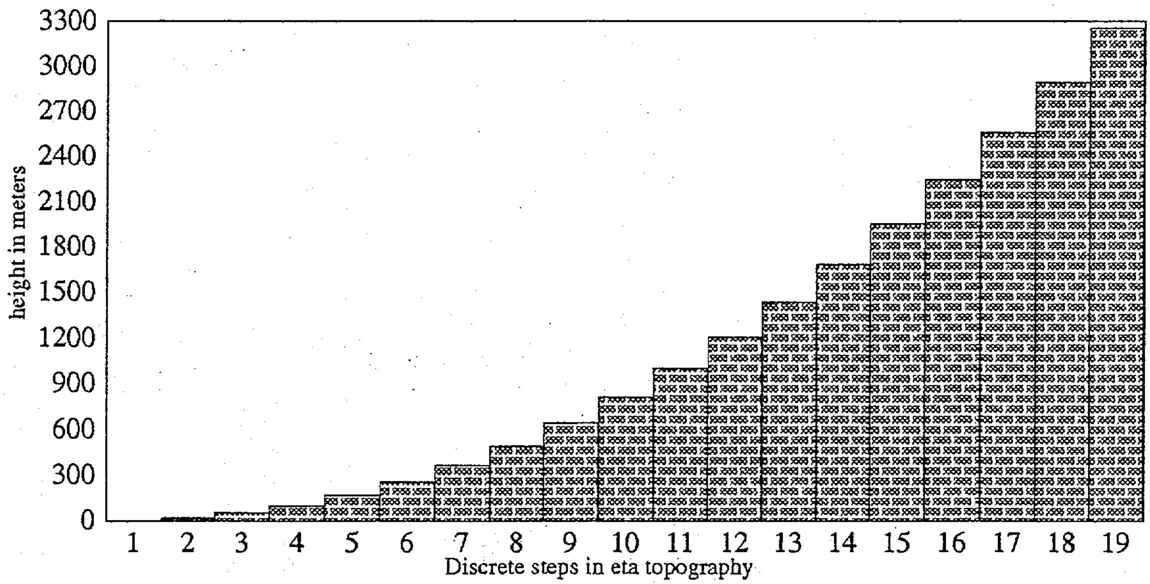

Fig. 2. Schematic of step topography used in operational Eta model. The top of each step coincides with an interface between eta layers. Note that the thickness of eta layers increases moving up from mean sea level.

The operational Eta runs with 38 vertical layers. The thickness of the layers varies with greatest vertical resolution near sea level and around 250 mb (to better resolve jet dynamics). The top of each step coincides exactly with one of the interfaces between the model's layers. Note that the thickness of the lowest eta layer above the model terrain is not horizontally homogeneous. This presents difficulties when posting terrain following fields. Such fields often exhibit strong horizontal gradients in mountainous regions. Vertical averaging over several eta layers, sometimes coupled with horizontal smoothing, minimizes this effect.

Model variables are staggered vertically as well as horizontally (Fig. 3). Temperature, specific humidity, and wind components are computed at the midpoint of eta layers. Turbulent kinetic energy is defined at the interfaces between layers. A no–slip boundary condition maintains zero wind components along the side of steps. Zero wind points are circled in Fig. 3.

The model uses a technique for preventing grid separation (Mesinger 1973, Janjić 1974) in combination with the split–explict time differencing scheme (Mesinger 1974, Janjić 1979). The fundamental time step for the operational Eta model is 200 seconds. This is the mass–momentum adjustment time scale. Advection, physi-

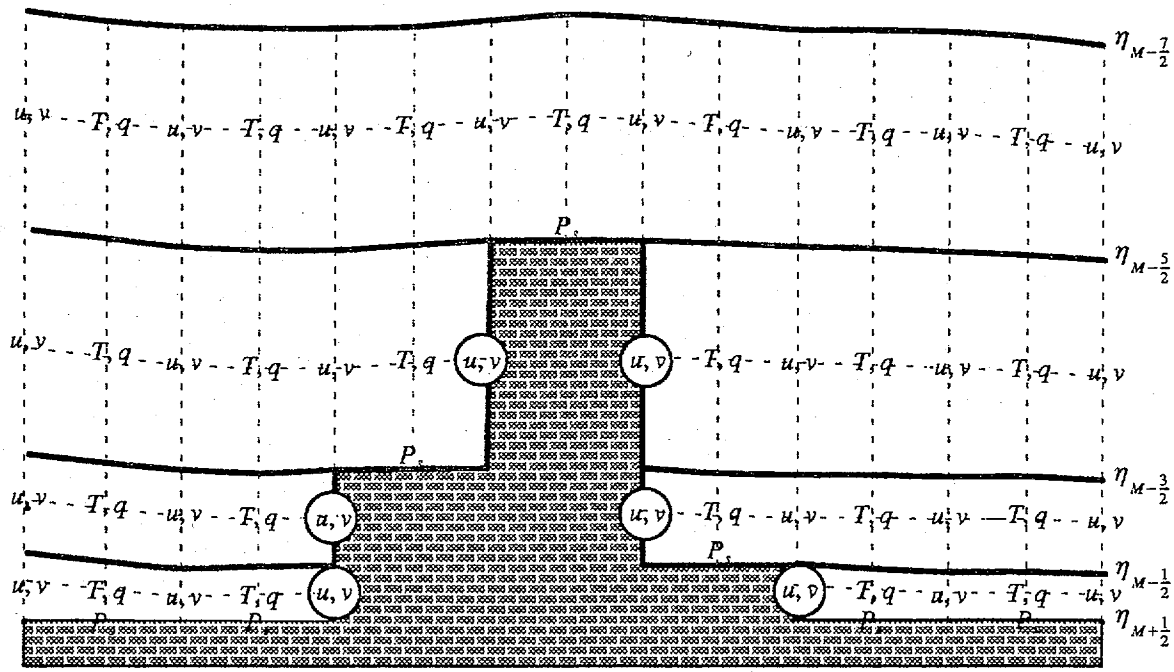

Fig. 3. Vertical cross section through Eta model with M layers. Temperature, specific humidity, zonal and meridional wind components (T, q, u, and v, respectively) are defined at the midpoint of each eta layer. P_s is the surface pressure. The circled wind components along the side of steps are identically zero as specified by the no–slip boundary used in the model.

cal processes, and radiation march at time steps which are integral multiples of the fundamental time step. The horizontal advection algorithm has a built–in strict nonlinear energy cascade control (Janjić, 1984). Vertical advection of moisture is based on the piecewise–linear method (Carpenter *et al.*, 1989).

The model includes a fairly sophisticated physics package (Janjić, 1990) consisting of the Mellor–Yamada Level 2.5 scheme (Mellor and Yamada 1974, 1982) in the free atmosphere, the Mellor–Yamada Level 2.0 scheme for the "surface" layer, and a viscous sublayer over the oceans (Zilitinkevitch, 1970). Surface processes are modeled after those of Miyakoda and Sirutis (1984) and Deardorff (1978). Diffusion utilizes a second order scheme with the diffusion coefficient depending on turbulent kinetic energy and deformation of the wind field. Large scale and parameterized deep and shallow convection are based on an approach proposed by Betts (1986) and Betts and Miller (1986). The radiation is the NMC version of the GFDL radiation scheme with interactive random overlap clouds.

The operational Eta runs from a static analysis based on Optimum Interpolation. First guess for the static analysis comes from the T–126 Global Data Assimilation System (approximately 105 km horizontal resolution). An assimilation system directly on the E grid is being developed and research is ongoing towards an adjoint Eta–based assimilation system. Boundary conditions for the model are provided by the previous cycle global model forecast, again, at T–126 resolution.

A more complete treatment of the Eta model is found in Black (1988) and Black (1993). The presentation above was intended to give the reader a general impression of the Eta model prior to discussing the Eta post processor below.

3. The Eta Post Processor – An Overview

The post processor serves two primary purposes. Foremost, the post processor interpolates forecast fields horizontally and vertically from the model grid to specified pressure levels on specified output grids. These posted fields include standard model output such as geopotential height, temperature, humidity (specific or relative), vertical motion, and u and v wind components. A second function of the post processor is to compute special fields from model variables. Under this list fall things such as tropopause level data, FD (flight data) level fields, freezing level information, and boundary layer fields.

With these purposes in mind the Eta post processor was designed to be modular, flexible, and relatively easy to use. A modular approach allows easy introduction of new routines to compute new output fields or test improved algorithms for currently posted fields. The post processor can run internal or external to the model. In the external mode the post processor may either be submitted as a separate batch job while the model is running or within the same batch job after completion of the model integration. The user controls posting of fields by editing a control file. Linking several control files together permits output of data on multiple grids or files. The structure of the control file was based on a similar file used with the NGM.

The simplest control file consists of three primary pieces. First is the header block. Here the user specifies the format of the posted fields and the output grid. Currently data may be posted in either of two forms. Data may be written using unformatted FORTRAN writes. This creates a (Cray) binary output file. File filters exist in UNICOS (the Cray operating system) to translate Cray binary to other binary formats. A more portable data format is Office Note 84 packing. Both operational and quasi–operational versions of the Eta model post fields according to Office Note 84 specifications. GRIB posting directly from the post is under development. For the interim GRIB versions of the Office Note 84 packed model output are generated by a separate program following execution of the post processor.

Data may be posted on the staggered E grid, a filled (i.e., regular) version of this grid, or any grid defined using standard NMC grid specifications. All computations involving model output are done on the staggered model grid. Bilinear interpolation is used to fill the staggered grid. A second interpolation is required to post data on a regular grid other than the filled E grid. This interpolation is also bilinear. Those grid points to which it is not possible to bilinearly interpolate a value to receive one of two values. A search is made from the outermost rows and columns of the output grid inward to obtain "known" values along the edge of the region to which interpolation was possible. Having identified these values the algorithm reverses direction and moves outward along each row and column. Grid points to which interpolation was not possible are set equal to the "known" value along their respective row and column. If after this operation corner points on the output grid do not have values they are assigned the field mean. Depending on the number of output fields requested the calculation of interpolation weights can take more CPU time than does posting the fields. For this reason interpolation weights may be pre–computed, saved, and read during post execution. The post retains the ability to compute these weights internally prior to posting any fields. A character flag in the header block controls this feature. A second character flag allows fields on different output grids to be appended to the same output file using the same or different data formats.

The second section of a control file lists available fields. By setting integer switches (0=off, 1=on) the user selects the fields and levels of interest. The current post processor has 110 unique output fields, some on multiple levels. Room exists for posting data on up to 60 vertical levels. In posting fields to an output grid smoothing or filtering of the data may be applied at any of three steps in the posting process. Fields may be smoothed on the staggered E grid, filtered on a filled E grid, or filtered on the output grid. Control of smoothing or filtering is via integer switches. Nonzero integers activate the smoother or filter with the magnitude of the integer representing the number of applications (passes) of the selected smoother or filter. The smoother coded in the post is a fourth order smoother which works directly on the staggered E grid. Once data is on a regular grid a 25 point Bleck filter is available. A nice property of this filter is its fairly sharp response curve.

Repeated applications will remove wavelengths twice the grid spacing while largely preserving field minima and maxima. Additional smoothing of posted fields can be realized in the interpolation process itself.

The last section of each control file is the end mark. This is a one line statement which tells the post processor to stop reading the control file and start posting requested fields. By having an explicit end mark the user only needs to specify the fields to be posted rather than all 110 available fields with switches turned off for unwanted fields. The order in which fields are requested is immaterial to the post processor. However, the order in which fields are written to the output file is fixed by the code. Figure 4 charts this ordering. Our discussion of the post processor in the Section 4 follows this flowchart.

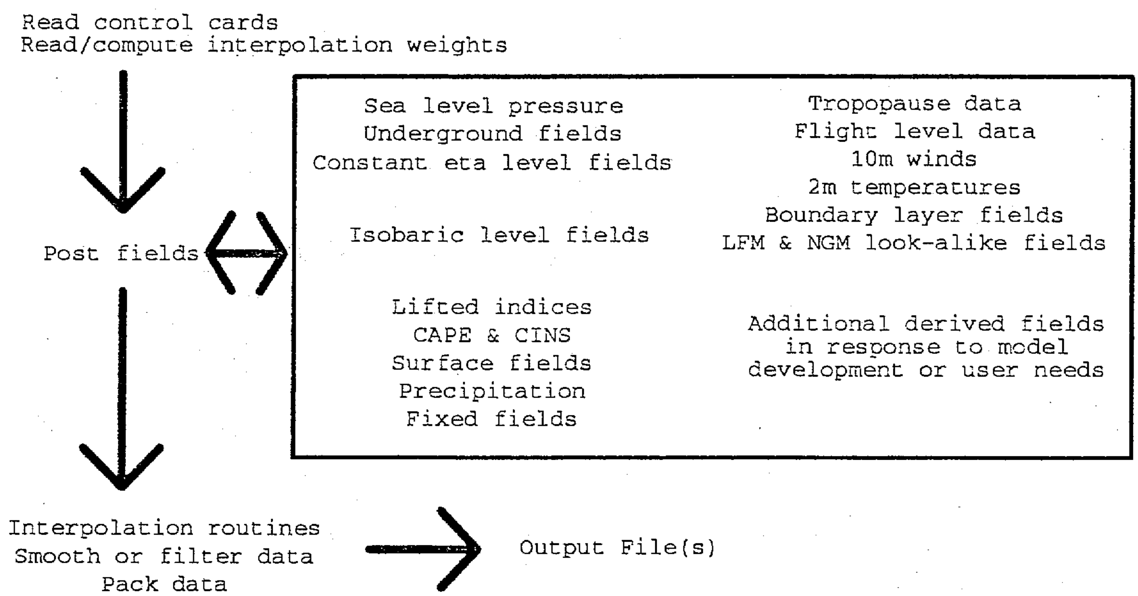

Fig. 4. Schematic of flow through post processor.

4. The Eta Post Processor – Details

The following sub-sections discuss fields available from the post and the algorithms used to derive these fields. The user of output from any model should understand exactly what is represented by posted model output. Such knowledge allows the user to make more discriminating decisions when using model output. Further, feedback from users can suggest alternative algorithms better suited to their needs.

4.1 Sea level pressure.

Sea level pressure is one of the most frequently used fields posted from any operational model. Just as surface pressure observations must be reduced to sea level so must forecast surface pressures be reduced to sea level. The question here is which of a myriad of reduction algorithms to use. Different reduction algorithms can produce significantly different sea level pressure fields given similar input data. The traditional approach is to generate "representative" underground temperatures in vertical columns and then integrate the hydrostatic equation downward. Saucier (1957) devotes several pages detailing the then current U.S. Weather Bureau reduction scheme. Cram and Pielke (1989) compare and contrast two reduction procedures using surface winds and pressure. References for other schemes may be found in their paper.

Sea level pressure is available from the Eta model using either of two reduction algorithms. One is based on a scheme devised by Mesinger (1990). The other is the "standard" NMC reduction algorithm. The methods differ in the technique used to create fictitious underground temperatures.

The "standard" reduction algorithm uses the column approach of vertically extrapolating underground temperatures from a representative above ground temperature. The algorithm starts with the hydrostatic equation in the form

$$\frac{dz}{-d(ln(p))} = \tau = \frac{R_d T_v}{g}$$

where

z = geometric height,

p = air pressure,

T_v = virtual temperature (approximately given by $T(1 + 0.608q)$; T, the dry air temperature and q, the specific humidity,

R_d = dry air gas constant, and

g = gravitational acceleration.

Mean sea level pressure, $p(msl)$, is computed at mass points using the formula $p(msl) = p(sfc) \times e^f$. The function $f = \frac{\tau^*}{z(sfc)}$, where τ^* is the average of τ at the model surface and mean sea level. The remaining question is how to determine these τ's.

In the NGM $\tau(sfc)$ and $\tau(msl)$ are first set using a 6.5°/km lapse rate from the first sigma layer. A similar approach was not successful in the Eta model due to the discontinuous nature of the step topography. Virtual temperatures are averaged over eta layers in the first 60 mb above the model surface. The resulting layer mean virtual temperature field is in turn horizontally smoothed before extrapolating surface and sea level temperatures.

In both the NGM and Eta $\tau(sfc)$ and $\tau(msl)$ are subject to the Sheull correction. Whether this correction is applied or not depends on the relation of the extrapolated τ's to a critical value $\tau_{cr} = \frac{R_d}{g} \times 290.66$.

The Sheull correction is applied in two cases:

(1) When only $\tau(msl)$ exceeds τ_{cr}, set $\tau(msl)$ to τ_{cr},

(2) When both $\tau(sfc)$ and $\tau(msl)$ exceed τ_{cr}, set $\tau(msl) = \tau_{cr} - \mu(\tau(sfc) - \tau_{cr})^2$,

where $\mu = 0.005 \times \frac{g}{R_d}$.

Once mean sea level pressure is computed a consistent 1000 mb height field is obtained using the relation $p(msl) - p(1000mb) = \varrho^* \times z(1000\ mb)$. This simple relationship itself can be used to obtain sea level pressure given 1000 mb geopotential heights and an assumed mean density. In the post the mean density, ϱ^*, is computed from $\tau^*$and p^* (the average in log pressure of $p(sfc)$ and $p(msl)$).

In contrast to the traditional column approach the Mesinger scheme uses horizontal interpolation to obtain underground virtual temperatures. The argument here is that it is physically more reasonable to create underground temperatures using atmospheric temperatures surrounding the mountain rather than extrapolating downward from a single temperature on the mountain. The step–mountain topography of the Eta model simplifies coding of this approach. The algorithm starts from the tallest resolved mountain and steps down through the topography. Virtual temperatures on each step inside the mountain (i.,e., underground) are obtained by solving a Laplace equation. Atmospheric virtual temperatures on the same step surrounding the mountain provide consistent, realistic boundary conditions. Once all underground temperatures have been generated the hydrostatic equation is integrated downward to obtain sea level pressure.

For selected sites the Eta model posts vertical profile (sounding) data plus several surface fields. The posting of profile information is not part of the post processor. Sea level pressures included in the profile data are available only from the Mesinger scheme. The standard and Mesinger schemes can produced markedly different sea level pressure fields given the same input data. This is especially true in mountainous terrain. The Mesinger scheme generally produces a smoother analysis, much as one might produce by hand.

4.2 Subterranean fields.

Over large portions of the Eta domain mean sea level is below the model terrain; hence the need for the sea level pressure reduction algorithms. Either algorithm generates underground temperatures and 1000 mb geopotential heights. Unresolved is the treatment of moisture and velocity fields below the model terrain. The approach taken in the Eta post processor follows the NGM. In each vertical column the lowest atmospheric eta layer relative humidity, zonal wind, meridional wind, and vertical motion fields are maintained below the model terrain. That is, there is constant extrapolation of the lowest atmospheric eta layer fields below the model surface. Underground specific humidity is adjusted to maintain the lowest atmospheric eta layer relative humidity given the underground temperatures generated by the sea level pressure reduction algorithm.

4.3 Constant eta and pressure fields.

Once underground temperature, humidity, and velocity fields have been specified there exists data on all eta layers. It is then possible to output data on constant eta or pressure levels. For either option the fields that may be posted are height, temperature (ambient, potential, and dewpoint), humidity (specific and relative), moisture convergence, zonal and meridional wind components, vertical velocity, absolute vorticity, the geostrophic streamfunction, and turbulent kinetic energy. Pressure may also be posted on constant eta layers.

Two options exist for posting eta layer data. Data may be posted from the n–th eta layer. This is simply a horizontal slice through the three dimensional model grid along the n–th eta layer. The slice disregards model topography. A second option is to post fields on the n–th eta layer above the model surface. From the definition of the eta coordinate it is clear that an eta–based terrain following layer is generally not a constant mass layer. In the current 38 layer operational Eta the thinnest first atmospheric eta layer is 20 meters thick while the deepest such layer (over a few grid points in the Colorado Rockies) is 360 meters thick. Despite differences in layer thickness, examining data in the n–th atmospheric eta layer does have merit. It permits the user to see what is truly happening in the n–th eta layer above the model surface and as such represents an eta–based boundary layer perspective. Additionally, the code can post mass weighted fields in six 30 mb deep layers stacked above the model surface (see Section 4.10). The operational Eta does not post eta layer data.

The more traditional way of viewing model output is on constant pressure surfaces. The post processor interpolates fields to nineteen isobaric levels (every 50 mb from 100 to 1000 mb). Vertical interpolation of temperature, specific humidity, vertical velocity, and turbulent kinetic energy is quadratic in log pressure. For horizontal and vertical winds the vertical interpolation is linear in log pressure. Consistent geopotential heights are deduced by integrating the hydrostatic equation using interpolated temperatures and specific humidity. Derived fields (e.g., dewpoint temperature, relative humidity, absolute vorticity, geostrophic streamfunction, etc.,) are computed from vertically interpolated base fields.

Still open is what to do if a requested isobaric level lies below the lowest model layer or above the model top (50 mb). Vertical and horizontal wind components above the model top are a constant extrapolation of the field at the uppermost model level. For isobaric levels below the lowest model layer the first atmospheric eta layer fields are posted. Turbulent kinetic energy (TKE) is defined at model interfaces rather than the midpoint of each layer. At isobaric layers above the model top the average TKE over the two uppermost model interfaces is constantly extrapolated. The same is done for pressure surfaces below the lowest model layer using TKE from the two lowest above ground interfaces.

Temperature, humidity, and geopotential heights are treated differently. For pressure levels above the model top the virtual temperature averaged over the two uppermost model layers is extrapolated assuming a standard atmospheric lapse rate. The specific humidity at the target level is set so as to maintain the relative humidity averaged over the two uppermost model layers. Geopotential heights are computed from the temperature and specific humidity using the hydrostatic equation. The treatment is the same for isobaric levels below the lowest model layer except that the averaging is over fields in the second and third model layers above the surface. Including data from the first atmospheric layer imposed a strong surface signature on the extrapolated isobaric level data.

4.4 Tropopause level data.

The post processor can generate the following tropopause level fields: pressure, temperature (ambient and potential), horizontal winds, and vertical wind shear. The greatest difficulty was coding an algorithm to locate the tropopause above each mass point. The procedure used in the Eta post processor is based on that in the NGM. Above each mass point a surface–up search is made for the first occurrence of two adjacent layers over which the lapse rate is less than a critical lapse rate. In both the NGM and Eta model the critical lapse rate is 2K/km. The midpoint (in log pressure) of these two layers is identified as the tropopause. A lower bound of 500 mb is enforced on the tropopause pressure. If no two layer lapse rate satisfies the above criteria the model top is designated the tropopause. Very strong horizontal pressure gradients result from this algorithm. Horizontal averaging over neighboring grid points prior to or during the tropopause search might minimize this effect. To date this alternative has not been coded. It might be more accurate to describe the current algorithm as one locating the lowest tropopause fold above 500 mb.

Linear interpolation in log pressure from the model layers above and below the tropopause provides the temperature. Recall that velocity points are staggered with respect to mass points. Winds at the four velocity points surrounding each mass point are averaged to provide a mass point wind. These mass point winds are used in the vertical interpolation to tropopause level. Vertical differencing between horizontal wind fields above and below the tropopause provides an estimate of vertical wind shear at the tropopause.

4.5 FD level fields.

Flight level temperatures and winds are posted at six levels, namely 914, 1524, 1829, 2134, 2743, and 3658 meters above the model surface. At each mass point a surface–up search is made to locate the model layers bounding the target FD level height. Linear in log pressure interpolation gives the temperature at the target height. Again, wind components at the four velocity points surrounding each mass point are averaged to provide a mass point wind. The wind averaging is coded so as to not include zero winds in the average. This can happen in mountainous terrain where the no slip boundary condition of the model maintains zero winds along the side of steps. Experimentation demonstrated that the averaging of winds to mass points minimized point maxima or minima in posted FD level wind fields. This process is repeated for all six flight level heights.

4.6 Freezing level data.

The post processor computes freezing level heights and relative humidities at these heights. The calculation is made at each mass point. Moving up from the model surface a search is made for the two model layers over which the temperature first falls below 273.16 K. Vertical interpolation gives the mean sea level height, temperature, pressure, and specific humidity at this level. From these fields the freezing level relative humidity is computed. These fields are used to generate the FOUS 40–43 NWS bulletins containing six hourly forecasts of freezing level heights and relative humidities for forecast hours twelve through forty–eight. The surface–up search algorithm means posted freezing level heights can never be below the model terrain. This differs from the LFM algorithm where underground heights were possible.

4.7 Sounding fields.

Several lifted indices are available from the Eta model. All are defined as being the temperature difference between the temperature of a lifted parcel and the ambient temperature at 500 mb. The distinction between the indices hinges on what parcel is lifted. The surface to 500 mb lifted index lifts a parcel from the first atmospheric eta layer. This lifted index is posted as the traditional LFM surface to 500 mb lifted index. The thinness of the first atmospheric eta layer in certain parts of the model domain imparts a strong surface signal on temperatures and humidities in this layer. In particular strong surface fluxes can create an unstable first atmospheric layer not representative of the layers above. The surface to 500 mb lifted index generally indicates larger areas of instability than other Eta lifted indices.

A second set of lifted indices are those computed from constant mass or "boundary" layer fields. The post can compute mass weighted mean fields in six 30 mb deep layers stacked above the model surface. Lifted indices may be computed by lifting a layer mean parcel from any of these layers. Of six possible lifted indices the operational Eta posts that obtained by lifting a parcel from the first (closest to surface) 30 mb deep layer.

The last lifted index available from the post processor is similar to the NGM best lifted index. In the NGM the best lifted index is the most negative (unstable) lifted index of resulting from lifting parcels in the four lowest sigma layers. The Eta best lifted index is the most negative lifted index resulting from lifting parcels in the six constant mass layers.

Two integral, sounding based fields are available from the Eta post processor: convective available potential energy (CAPE) and convective inhibition (CINS). The operational Eta posts only CAPE, not CINS. As coded in the post processor CAPE is the column integrated quantity (Cotton and Anthes, 1989)

$$CAPE = g \int_{lcl}^{z^*} (\ln \theta_p - \ln \theta_a) \, dz$$

where,

θ_p = parcel equivalent potential temperature,

θ_a = ambient equivalent potential temperature,

lcl = lifting condensation level of parcel, and

z^* = upper integration limit.

The parcel to lift is selected as outlined in Zhang and McFarlane (1991). The algorithm locates the parcel with the warmest equivalent potential temperature (Bolton, 1980) in the lowest 70 mb above the model surface. This parcel is lifted from its lifting condensation level to at least 500 mb. Lifting above 500 mb continues until the parcel is negatively buoyant. During the lifting process positive area in each layer is summed as CAPE, negative area as CINS. Note that the parcel is lifted to at least 500 mb, regardless of buoyancy. This differs from most definitions of CAPE. Typical is Atkinson's (1981) definition of CAPE

$$CAPE = g \int_{lcl}^{z^*} \left(\frac{\theta_p - \theta_a}{\theta_a} \right) dz$$

with z^* being the equilibrium level. Apart from the difference in integration limits this definition of CAPE and the one coded in the post processor produce qualitatively similar results. This is easily seen from the power series expansion of $\ln \theta_p - \ln \theta_a = \ln\left(\frac{\theta_p}{\theta_a}\right) = \frac{\theta_p - \theta_a}{\theta_a} - \frac{1}{2}\left(\frac{\theta_p - \theta_a}{\theta_a}\right)^2 + \cdots$ which shows the integrands to be related.

Posted CAPE values can indicate a greater potential for convection than may be realized. Two factors contribute to this effect. First, the search to determine which parcel to lift starts from the first eta layer above the surface. As mentioned above the thinness of this layer over certain parts of the domain imparts a strong surface signal on temperatures and humidities in this layer. Instabilities in the first atmospheric eta layer may not be representative of the layers above. Secondly, the CAPE calculation forcefully lifts all parcels to at least

500 mb regardless of any inversion(s) which would cap or prevent convection in the atmosphere. These points should be kept in mind when using CAPE values posted from the operational Eta.

Random overlap clouds are included in the Eta model radiation package. This code is based on that in the NMC global spectral model (Campana and Caplan (1989), Campana *et al.* (1990)). Both stratiform and convective clouds are parameterized. Key variables in the parameterization are relative humidity and convective precipitation rates. Clouds fall into three categories: low (approximately 640 to 990 mb), middle (350 to 640 mb), and high (above 350 mb). Fractional cloud coverage for stratiform clouds is computed using a quadratic relation in relative humidity (Slingo, 1980). The operational Eta posts neither stratiform nor convective cloud fractions.

In addition to cloud fractions the post processor can compute lifting condensation level (lcl) pressure and height above each mass point. These calculations appear quite sensitive to the definition of the parcel to lift. Experiments are ongoing to find an optimal definition of this parcel. Under certain situations the convective condensation level or level of free convection may be more indicative of cloud base heights. The modular design of the post processor simplifies the development of such routines. Currently neither lcl pressures nor heights are posted from the operational Eta.

4.8 Surface based fields.

The post processor can output surface pressure, temperature (ambient, dewpoint, and potential), and humidity (specific and relative). Surface temperatures and humidities are strictly surface based and should not be interpreted as being indicative of shelter level measurements. The model carries running sums of total, grid–scale, and convective precipitation. The accumulation period for these precipitation amounts is set prior to the model run and is currently twelve hours. Interpolation of accumulated precipitation amounts from the model grid to other output grids utilizes an area conserving interpolation scheme. Other surface based fields that can be posted include incoming and outgoing radiation, roughness length, friction velocity, and coefficients proportional to surface momentum and heat fluxes.

Static surface fields may also be posted. These are the geodetic latitude and longitude of output grid points, the land–sea mask, the sea ice mask, and arrays from which three dimensional mass and velocity point masks may be reconstructed. The land–sea mask defines the land–sea interface in the model. Three dimensional mass and velocity point masks vertically define model topography. For operational models the practice is to post model output atop background maps. This assumes the model geography matches that of the background map. A one to one correspondence between the two is obviously not possible. The same remark holds true in the vertical. These comments should be keep in mind when interpreting output from any model.

4.9 10 m winds and 2 m temperatures.

The post processor computes anemometer level (10 meter) winds and shelter level (2 meter) temperatures. Gradients of wind speed and temperature can vary by several orders of magnitude in the surface–layer. Direct application of the Mellor–Yamada Level 2.0 equations in the surface–layer would require additional model layers to adequately resolve these gradients. A computationally less expensive approach is to use a bulk layer parametrization of the surface–layer consistent with the Mellor–Yamada Level 2.0 model. Lobocki (1993) outlined an approach to derive surface–layer bulk relationships from higher closer models. Assuming a horizontally homogenous surface layer at rest the Monin–Obukov theory maintains that dimensionless gradients of wind speed and potential temperature at height z (in the surface–layer) may be represented as a function of a single variable $\zeta = \frac{z}{L}$. The length scale L is the Monin–Obukhov scale. A second important surface–layer parameter is the flux Richardson number R_f which quantifies the relative importance of two production terms in the turbulent kinetic energy equation. Using the Mellor–Yamada Level 2.0 model Lobocki derived a fundamental equation relating internal or surface–layer parameters ζ and R_f with external or bulk characteristics of the surface–layer. Equations consistent with this fundamental equation relating the wind speed, U, or potential temperature, Θ, between two levels, z_1 and z_2, in the surface layer are

$$U(z_2) - U(z_1) = \frac{U_*}{\varkappa} \Phi_U(z_1, z_2, L)$$

$$\Theta(z_2) - \Theta(z_1) = \frac{\Theta_*}{\varkappa} \Phi_\Theta(z_1, z_2, L)$$

where

L = Monin–Obukhov scale,

U_*, Θ_* = constant coefficients, and

$\varkappa$ = von–Kármán constant.

The functions Φ_U and Φ_Θ are integrated forms of similarity functions for dimensionless differences of the quantity U or Θ across the layer z_1 to z_2.

Specifically, for $S = U$ or Θ

$$\Phi_s(z_1, z_2, L) = \phi_s(0) \times \left[\ln\left(\frac{z_2}{z_1}\right) + \Psi_s(\zeta_2) - \Psi_s(\zeta_1)\right]$$

where $\phi_s(0)$ is a constant, $\zeta_1 = \frac{z_1}{L}$, and $\zeta_2 = \frac{z_2}{L}$. The function $\Psi_s(\zeta)$ is given by equation (48) in Lobocki's paper for $S = U$ and (49) for $S = \Theta$.

When applying these equations to compute anemometer level winds or shelter level temperatures the height z_2 refers to values in the first eta layer above ground. The height z_1 refers to the target level in the surface layer (either 10 or 2 meters). The dependence of $\Psi_s(\zeta)$ on the Monin–Obukhov height ζ introduces a physically reasonable stability–based variability in computed anemometer level winds and shelter temperatures. In the absence of strong synoptic forcing both anemometer level winds and shelter temperatures exhibit a typical diurnal cycle.

4.10 Boundary layer fields.

The Eta model does not explicitly forecast fields in a boundary layer. Additionally, the thickness of the n–th eta layer above the model terrain varies horizontally. The post processor computes mass–weighted mean fields in six 30 mb deep layers above the model surface. Note that since the thickness of the n–th eta layer above the surface varies horizontally the number of layers used in computing mass weighted means is not horizontally homogenous. Variables that can be posted from any or all of the six layers are pressure, temperature (ambient, potential, and dewpoint), humidity (specific and relative), moisture convergence, horizontal wind components, vertical velocity, and precipitable water. The precipitable water is that amount obtained by integration over the constant mass layer. The operational Eta posts all possible boundary layer fields in the first (lowest) 30 mb layer above the surface. Additionally temperature, relative humidity, and winds are posted from the third and sixth constant mass layers.

Considerable time was spent developing an algorithm to mimic the behavior of LFM boundary layer winds. Boundary layer winds from the LFM did not exhibit a diurnal cycle typical of those from the NGM and Eta model. Rather, LFM boundary layer winds appeared geostrophic with a superimposed cross isobaric turning towards lower pressure. To reproduce this effect using the Eta model we start with geostrophic winds computed from heavily smoothed sea level pressure or 1000 mb heights. The resulting geostrophic wind components are turned using the classic Ekman spiral equations (Section 8.5.2 of Haltiner and Williams, 1980). A rotation parameter controls the amount of the cross contour flow. After much experimentation a suitable rotation parameter along with appropriate smoothing was found to produce a wind field very comparable to the LFM boundary layer winds. This method is not currently used in the operational Eta.

4.11 LFM and NGM look–alike fields.

In addition to posting standard data on pressure surfaces or deriving other fields from model output, the post processor generates fields specific to the LFM and NGM using Eta model output. These fields are written to the output file using LFM or NGM labels. The primary reason for including these look–alike fields was to ensure compatibility of posted Eta model output with existing graphics and bulletin generating codes.

The post computes equivalents to fields in the NGM first (S1=0.98230), third (S3=0.89671), and fifth (S5=0.78483) sigma layers data as well as layer mean relative humidities and a layer mean moisture convergence field. Recall the definition of the sigma coordinate,

$$\sigma = \frac{p - p_t}{p_s - p_t}$$

Given the pressure at the top of the model (p_t = 50 mb) and the forecast surface pressure p_s target sigma levels are converted to pressure equivalents. Vertical interpolation from the eta layers bounding each target pressure provides an eta–based approximation to the field on the target sigma level. This calculation is repeated at each horizontal grid point to obtain eta–based sigma level S1, S3, S5 temperatures, S1 relative humidity, and S1 u and v wind components. Since surface pressure is carried at mass points a four point average of the winds surrounding each mass point is used in computing the S1 u and v wind components. A check is made to ensure zero winds are not included in this average. S3 and S5 relative humidities are layer means over the eta layers mapping into sigma layers 0.47 to 0.96 and 0.18 to 0.47, respectively.

The FOUS 60–78 NWS bulletins are generated from the NGM look–alike fields and other posted fields. These bulletins contain initial condition and six hourly forecasts out to forecast hour 48 for thirteen parameters at sites over the U.S., Canada, and coastal waters. Table 1 identifies which Eta fields are used in generating these bulletins.

LFM look–alike fields include three layer mean relative humidities and a partial column precipitable water. An approach similar to that used for the NGM is not directly applicable. The distinction arises due to the vertical structure of the LFM. The approach taken here was to assume a sigma based vertical coordinate in the

Table 1. Posted Eta model fields used to generate FOUS 60–78 NWS bulletins.

Fous 60–78 entry	Posted Eta field used
PTT (accumulated precipitation)	total accumulated precipitation
R1 (sigma layer 1 relative humidity)	NGM look–alike S1 relative humidity
R2 (0.47 to 0.96 layer mean relative humidity)	NGM look–alike S3 relative humidity
R3 (0.18 to 0.47 layer mean relative humidity)	NGM look–alike S5 relative humidity
VVV (700 mb vertical velocity)	700 mb vertical velocity
LI (best (NGM four layer) lifted index)	Eta best (six layer) lifted index
PS (sea level pressure)	"standard" reduction sea level pressure
DDFF (sigma layer 1 wind speed and direction)	NGM look–alike S1 u and v winds
HH (1000–500 mb layer thickness)	1000 and 500 mb geopotential heights
T1 (sigma layer 1 temperature)	NGM look–alike S1 temperature
T3 (sigma layer 3 temperature)	NGM look–alike S3 temperature
T5 (sigma layer 5 temperature)	NGM look–alike S5 temperature

LFM and identify appropriate sigma levels bounding LFM layer mean fields. The sigma levels used for layer mean relative humidities are 0.33 to 1.00, 0.66 to 1.00, and 0.33 to 0.66. For precipitable water the range in sigma is 0.33 to 1.00. Given these sigma bounds the same sigma to eta mapping used for the NGM fields is applied here.

5. Summary

In this Office Note we have reviewed the output capabilities of the Eta post processor. Preliminary to describing the post processor was a brief review of the Eta model. The emphasis here was on the horizontal and vertical layout of model variables. Given this background we previewed the Eta post processor in general terms. Key points included the modular design of the post processor and ease of use. The user controls the post via a control file. In this control file the user not only specifies which fields to post but also on which grid to post the data and the format to use. Following this was a field by field description of the algorithms used to derive posted fields. Users of output from any model should understand how the output is generated. This information allows the user to better use posted model output.

Development continues on the Eta model and so will work continue on the post processor. Most immediate is the need to include the ability to post fields directly in GRIB. As users become more familiar with the Eta model it is envisioned their feedback will suggest the addition or deletion of routines. Such communication can play an important but often overlooked role in development.

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Appendix 1: Fields Posted from the Operational Eta

7.1 Discussion

With the introduction of any new forecast model it is important to document what is available, where it is, and in what format it is stored. This appendix attempts to fill this void by listing several sources of operational Eta output. It does not address questions of accessing or unpacking the data. The last section lists LFM products replaced by Eta products as of June 1993.

The operational Eta runs twice daily out to forecast hour 48. Fields are posted every six hours starting from the initial conditions. The post processor generates two sets of sequential access Office Note 84 packed output files, "FM" and "XP" files. To facilitate dissemination of Eta model output to the field across existing communication circuits it was necessary to post Eta model output on the LFM forecast grid (Office Note 84 grid 26). These files are the FM files. Note that grid 26 has a mesh length of 190 km while the Eta model runs on an approximately 80 km mesh. Obviously, significant detail can sometimes be lost in this interpolation. To make the FM files completely compatible with pre–existing codes a few additional fields posted to grids other than grid 26 are appended to the FM files.

The XP files contain data posted to Office Note 84 grid 104, the NGM "super–C" grid. The horizontal resolution of this grid is approximately 90 km, comparable to that of the operational Eta. Precipitation forecasts on the Eta model grid (90) are appended to this file. The XP files contain the most complete posting of Eta model output. Their design and naming ("XP") was chosen to mimic similar files generated by the RAFS. FM files contain a subset of the data posted to XP files.

The LFM posted an analysis to Office Note 84 grid 5 at the start of its integration. This analysis was a true analysis and not the initial conditions used to start the LFM. The operational Eta posts its initial conditions to grid 5 as well as to the FM and XP files. When the eta–based assimilation system is made operational a true analysis may be posted to grid 5 if deemed necessary.

Operational Eta model output is archived in two databases. Permanent archiving of model output began with the June 1993 implementation. The permanent database is the NMC Run History Tapes. The sequential access, Office Note 84 packed XP and FM files are written to these tapes every cycle. Documentation for this database is found in the NMC Handbook (Stackpole, 1990).

A second database for Eta forecasts is a rotating archive maintained by Development Division, NMC. The XP files are written to a 36 day rotating ETAX archive. Not all fields posted to the XP file are written to the ETAX archive. Further, data along the edges of grid 104 is stripped off leaving the smaller subgrid 105 which is then archived. The FM files are written to a 7 day rotating archive named ETLX. Here data is archived on grid 26. Not all fields posted to the FM files are written to this archive. Table 3 lists which fields are available on the ETAX and ETLX archives. Documentation describing the rotating archive is "NMC Development Division Rotating Random Access Archive: User Documentation" (Keyser 1990).

On a daily basis Eta model output is available in four forms: sequential Office Note 84 holding files, Office Note 84 VSAM files, GRIB1 formatted files, and PC–Grids files. These files reside on the NAS 9000 operated by the Department of Commerce at the Suitland Federal Center. Table 1 lists the names of these files on the NAS 9000. The sequential access, Office Note 84 holding files are simply the XP and FM files generated by the post processor. NAS 9000 jobs create VSAM files from these sequential files. Other than the file format the VSAM and holding file versions of the XP and FM files are identical. Until GRIB is added to the post processor, NAS 9000 codes generate GRIB1 files from the sequential XP and FM files. The GRIB1 XP files contain data over the smaller grid 105. All fields on the XP and FM files are converted to GRIB1. The last format for posted Eta forecasts is PC–Grids. In this reformatting process grid 104 data is reduced to grid 105. Not all fields posted to the XP and FM files are written to PC–Grids files. Table 4 lists which fields are posted to PC–Grids files. Note that the exact contents of the PC–Grids files will likely change in response to future user requests.

Table 5 lists the first four hexadecimal words of the Office Note 84 label with which operational Eta fields are packed. Admittedly, this table is of little use to users of the GRIB1 or PC–Grids Eta files. However, since all forms of Eta model output start from the Office Note 84 packed data sets it was decided to include these labels in this Office Note. They definitively tell any user of the Office Note 84 packed Eta data sets what each field is.

The last table (6) lists products generated from the operational Eta as of June 1993. Many of these replaced LFM products. Others are unique to the Eta model. Note that Eta–based FOUS 60–78 NWS bulletins use the NGM format and **not** that of the LFM. In the months following the June 1993 implementation additional Eta based products will gradually come on line.

This concludes this brief overview of the availability and dissemination of operational Eta model output. Following are several tables mentioned above. Please note that the specific contents of these listings are subject to change as the Eta model implementation progresses.

7.2 Table 1. Where is it?

Where can one find all this data? The above mentioned data sets reside on the NAS 9000 operated by the Department of Commerce at the Suitland Federal Complex. The table below lists the filenames of these datasets.

File type	NAS 9000 dataset name
Office Note 84 sequential analysis	NMC.PROD.LFANL.HOLD.ETA
Office Note 84 sequential XP	NMC.PROD.LF*xx*XP.HOLD.ETA
Office Note 84 sequential FM	NMC.PROD.LF*xx*.HOLD.ETA
Office Note 84 VSAM XP	NMC.PROD.VLF*xx*XP.T*cc*Z.ETA
Office Note 84 VSAM FM	NMC.PROD.VLF*xx*.T*cc*Z.ETA
GRIB1 XP	COM.CED1.LF*xx*XP.T*cc*Z.ETA
GRIB1 FM	COM.CED1.LF*xx*.T*cc*Z.ETA
PC–Grids XP	USR.WD20.PCGRIDS.T*cc*Z.ETXC
PC–Grids FM	USR.WD20.PCGRIDS.T*cc*Z.ETAX

xx is the forecast hour in six hourly increments from 00 through 48.
cc is the forecast cycle, 00 or 12.

7.3 Table 2. Contents of Operational Eta Sequential Access, VSAM, and GRIB1 Files

The post processor generates two primary sequences of output files, the XP and FM files. As generated by the post these are sequential access, Office Note 84 packed datasets. All fields on the XP and FM files are written to the NMC Run History tapes as sequential access, Office Note 84 packed datasets. Jobs on the NAS 9000 generate VSAM and GRIB1 versions of these files. The VSAM files are identical to the sequential access files in all aspects except file format. GRIB1 XP files are on grid 105, a subset of grid 104. Otherwise GRIB1 XP and FM files are similar to their sequential access counterparts. The table below lists the fields posted to the XP, FM, and analysis files. The numbers in the columns are the Office Note 84 grid to which the post processor interpolates the data. Recall that some fields in the FM file are posted to more than one output grid. These fields and grid types are noted below. A "NA" means that the field is not available on that output file.

Field	XP file	FM file	Analysis file
Mesinger sea level pressure	104	26	NA
NMC standard sea level pressure	104	26,101,104	5
Geopotential height, temperature, relative humidity, u wind, v wind, and vertical velocity every 50mb from 100 to 1000mb	104	NA	NA
Geopotential height, u wind, v wind, and vertical velocity at 100, 150, 200, 250, 300, 400, 500, 700, 850, 950, and 1000mb	NA	26,	NA
Geopotential height, temperature, u wind, and v wind at 100, 150, 200, 250, 300, 400, 500, 700, 850, and 1000mb	NA	NA	5
Vertical velocity at 700mb	NA	101,104	NA
Temperature and relative humidity at 100, 200, 250, 300, 400, 500, 700, 750, 800, 850, 900, 950, and 1000 mb. Relative humidity is not posted at 100, 200, or 250mb	NA	26	NA
Dewpoint temperature and specific humidity at 300, 400, 500, 700, 850, and 1000mb	104	26	NA
Absolute vorticity at 250, 500, 700, 850, and 1000mb	104	26	NA
Geostrophic streamfunction at 500mb	104	26	NA
Surface, first boundary layer, and "Best" lifted indices	104	26	NA
CAPE	104	26	NA
Surface pressure, geopotential, temperature, and specific humidity	104	NA	NA
Surface pressure and geopotential	NA	26	NA
Surface pressure	NA	101	NA
Surface temperature	NA	NA	5
12 hour accumulated total, grid–scale, and convective precipitation	104, 90	26,101	NA

Field	XP file	FM file	Analysis file
12 hour accumulated total precipitation	NA	104	NA
Total column precipitable water	104	26	NA
Anemometer (10m) level u and v winds	104	26	NA
Shelter (2m) temperature	104	NA	NA
Tropopause pressure, temperature (ambient and potential), u and v winds, and vertical wind shear	104	26	NA
Tropopause pressure and temperature (ambient and potential)	NA	NA	5
Flight data (FD) level temperature, u and v winds at 914, 1524, 1829, 2134, 2734, and 3658 meters	104	26	NA
Freezing level height (agl) and relative humidity	104	26	NA
First (lowest) boundary layer pressure, temperature (ambient, potential, and dewpoint), humidity (relative and specific), u and v winds, vertical velocity, moisture convergence, and precipitable water	104	26	NA
Third boundary layer temperature, relative humidity, u and v winds, and vertical velocity	104	NA	NA
Sixth boundary layer temperature, relative humidity, u and v winds, and vertical velocity	104	NA	NA
LFM 0.33–1.00 layer mean relative humidity	104	26	5
LFM 0.66–1.00 layer mean relative humidity	104	26	5
LFM 0.33–0.66 layer mean relative humidity	104	26	5
LFM 0.33–1.00 precipitable water	104	26	NA
NGM sigma level 0.98230 pressure, temperature, humidity (specific and relative), u wind, and v wind	104	26	NA
NGM sigma level 0.98230 temperature, u wind, and v wind	NA	101	NA
NGM sigma level 0.89671 temperature	104	26	NA
NGM sigma level 0.78483 temperature	104	26	NA
NGM 0.47–1.00 layer mean relative humidity	104	26	NA
NGM 0.47–0.96 layer mean relative humidity	104	26	NA
NGM 0.18–0.47 layer mean relative humidity	104	26	NA
NGM 0.84–0.98 layer mean relative humidity	104	26	NA
NGM 0.85–1.00 layer mean moisture convergence	104	26,101,104	NA

7.4 Table 3. Contents of Operational Eta Rotating Archives

The sequential access, Office Note 84 packed XP files are written to a 36 day archive, ETAX. Data on the smaller grid 105 is archived for forecast hours 00 (initial condition) through 48 at six hour intervals. The seven day FM archive, ETLX, archives data on grid 26 for forecast hours 00, 12, 24, 36, and 48. The grid numbers below are Office Note 84 grid types. NA denotes not available.

Field	ETAX	ETLX
Mesinger and NMC standard sea level pressure	105	26
Geopotential height, temperature, relative humidity, u wind v wind, and vertical velocity every 50mb from 100 to 1000mb. Relative humidity is not available at 100, 150, 200, and 250mb.	105	NA
Geopotential height, u wind, v wind, and vertical velocity at 100, 200, 250, 300, 400, 500, 700, 850, 950, and 1000mb	NA	26,
Specific humidity and dewpoint temperature at 300, 400, 500, 700, 850, and 1000mb.	NA	26
Relative humidity at 300, 400, 500, 700, 750, 800, 900, 950, and 1000mb.	NA	26
250, 500, 700, 850, and 1000mb absolute vorticity	NA	26
500mb geostrophic streamfunction	NA	26
Surface lifted index	105	26
"Best" lifted index	NA	26
Surface pressure and geopotential	105	26
12 hour accumulated total and convective precipitation	105,90	26
Total column precipitable water	NA	26
LFM 0.33–1.00 precipitable water	NA	26
First boundary layer precipitable water	NA	26
Anemometer (10m) u and v winds	NA	26
Tropopause pressure, temperature, u wind, and v wind	NA	26
NGM sigma 0.98230 pressure, temperature, specific humidity relative humidity, u wind and v wind.	NA	26
NGM sigma 0.89671 and 0.78483 temperature	NA	26
NGM sigma 0.18–0.47, 0.47–1.00, and 0.47–0.96 layer mean relative humidities.	NA	26
NGM sigma 0.85–1.00 layer mean moisture convergence	NA	26

7.5 Table 4. Contents of Operational Eta PC–Grids Files

The table below lists operational Eta fields available in PC–Grids format. The smaller grid 105 is extracted from the XP files and converted to PC–Grids format. AVBL means the field is on the file; NA, not available.

Field	XP files	FM files
NMC standard sea level pressure	AVBL	AVBL
Geopotential height, temperature, u wind, v wind, and vertical velocity at 100, 150, 200, 250, 300, 400, 500, 700, 850, and 1000mb. The FM PC–Grids file does not contain 100 or 150mb data.	AVBL	AVBL
500mb absolute vorticity	NA	AVBL
Relative humidity at 300, 400, 500, 700, 850, and 1000mb	AVBL	NA
Specific humidity at 300, 400, 500, 700, 850, and 1000mb	NA	AVBL
Surface pressure and geopotential The FM PC–Grids file only contains surface pressure.	AVBL	AVBL
Surface lifted index	AVBL	AVBL
12 hour accumulated total and convective precipitation	AVBL	AVBL
Total column precipitable water	AVBL	AVBL
Anemometer (10m) winds	NA	AVBL
First boundary layer pressure, temperature, relative humidity, u wind, and v wind.	AVBL	AVBL

7.6 Table 5. Office Note 84 Labels of Posted Eta Fields

The table below lists all the fields posted from the operational Eta along with the first four hexadecimal words of the Office Note 84 label with which each field is packed. We assume the reader is familiar with the Office Note 84 packing convention. The listing below is for 00 hour posted fields. The same fields are written every six hours.

Posted field	Word 1	Word 2	Word 3	Word 4
Mesinger sea level pressure	00808A00	00000000	00000000	00000000
NMC standard sea level pressure	00808000	00000000	00000000	00000000
500mb geopotential height	00100800	00C35082	00000000	00000000
500mb temperature	01000800	00C35082	00000000	00000000
500mb dewpoint temperature	01100800	00C35082	00000000	00000000
500mb relative humidity	05800800	00C35082	00000000	00000000
500mb specific humidity	05F00800	00C35082	00000000	00000000
500mb u wind component	03000800	00C35082	00000000	00000000
500mb v wind component	03100800	00C35082	00000000	00000000
500mb vertical velocity	02800800	00C35082	00000000	00000000
500mb absolute vorticity	04800800	00C35082	00000000	00000000
500mb geostrophic streamfunction	05000800	00C35082	00000000	00000000
100mb data		00271082		
150mb data		003A9882		
200mb data		004E2082		
250mb data		0061A882		
300mb data		00753082		
350mb data		0088B882		
400mb data		009C4082		
450mb data		00AFC882		
550mb data		00D6D882		
600mb data		00EA6082		
650mb data		00FDE882		
700mb data		01117082		
750mb data		0124F882		
800mb data		01388082		
850mb data		014C0882		
900mb data		015F9082		
950mb data		01731882		
1000mb data		00271081		
Tropopause pressure	00808200	00000000	00000000	00000000
Tropopause temperature	01008200	00000000	00000000	00000000
Tropopause u wind component	03008200	00000000	00000000	00000000
Tropopause v wind component	03108200	00000000	00000000	00000000
Tropopause vertical wind shear	03408200	00000000	00000000	00000000
FD temperature at 914m	01000100	01650882	00000000	00000000
FD u wind component at 914m	03000100	01650882	00000000	00000000
FD v wind component at 914m	03100100	01650882	00000000	00000000
FD data at 1524m		003B8881		
FD data at 1829m		00477281		
FD data at 2143m		00535C81		

Posted field	Word 1	Word 2	Word 3	Word 4
FD data at 2743m	006B2681			
FD data at 3658m	008EE481			
Freezing level height	00101000	006AB482	00000000	00000000
Freezing level relative humidity	05801000	006AB482	00000000	00000000
*Note: In the FM files word 2 is 006AB382, corresponding to 273.15K.				
Lifted index – surface to 500mb	07000800	00C35082	20008100	00000000
Lifted index – boundary layer 1	07000800	00C35082	20009000	00271084
Lifted index –"best"	07409400	01499085	20009400	017FB685
CAPE	09D08100	00000000	00000000	00000000
Surface pressure	00808100	00000000	00000000	00000000
Surface height	00108100	00000000	00000000	00000000
Surface temperature	01008100	00000000	00000000	00000000
Surface specific humidity	05F08100	00000000	00000000	00000000
Accumulated total precipitation	05A08100	30000000	0000000C	00000000
Accumulated convective precipitation	05E08100	30000000	0000000C	00000000
Accumulated non–convective precipitation	06908100	30000000	0000000C	00000000
Total column precipitable water	05909400	00000000	20009400	00271084
Anemometer (10m) u wind component	03000600	00271083	00000000	00000000
Anemometer (10m) v wind component	03100600	00271083	00000000	00000000
Shelter (2m) temperature	01000600	00000000	00000000	00000000
Boundary layer 1 pressure	00809000	00000000	20009000	00271084
Boundary layer 1 temperature	01009000	00000000	20009000	00271084
Boundary layer 1 potential temperature	01309000	00000000	20009000	00271084
Boundary layer 1 dewpoint temperature	01109000	00000000	20009000	00271084
Boundary layer 1 relative humidity	05809000	00000000	20009000	00271084
Boundary layer 1 specific humidity	05F09000	00000000	20009000	00271084
Boundary layer 1 u wind component	03009000	00000000	20009000	00271084
Boundary layer 1 v wind component	03109000	00000000	20009000	00271084
Boundary layer 1 vertical velocity	02809000	00000000	20009000	00271084
Boundary layer 1 precipitable water	05909000	00000000	20009000	00271084
Boundary layer 1 moisture convergence	06709000	00000000	20009000	00271084
Boundary layer 3 data				01695485
Boundary layer 6 data				01462C85
LFM 0.33–1.00 mean relative humidity	05809100	00823585	20009000	00271084
LFM 0.66–1.00 mean relative humidity	05809100	01046B85	20009100	00271084
LFM 0.33–0.66 mean relative humidity	05809100	00823585	20009100	01046B85
LFM 0.33–1.00 precipitable water	05909100	00823585	20009000	00271084
NGM 0.98230 sigma pressure	00809400	017FB685	00000000	00000000
NGM 0.98230 sigma temperature	01009400	017FB685	00000000	00000000
NGM 0.98230 sigma specific humidity	05F09400	017FB685	00000000	00000000
NGM 0.98230 sigma relative humidity	05809400	017FB685	00000000	00000000
NGM 0.98230 sigma u wind component	03009400	017FB685	00000000	00000000
NGM 0.98230 sigma v wind component	03109400	017FB685	00000000	00000000
NGM 0.89671 sigma temperature	01009400	015E4785	00000000	00000000
NGM 0.78483 sigma temperature	01009400	01329385	00000000	00000000
NGM 0.47–1.00 mean relative humidity	05809400	00B85785	20009400	00271084
NGM 0.47–0.96 mean relative humidity	05809400	00B85785	20009400	0178D685
NGM 0.18–0.47 mean relative humidity	05809400	00466385	20009400	00B85785
NGM 0.84–0.98 mean relative humidity	05809400	01499085	20009400	017FB685
NGM 0.85–1.00 mean moisture convergence	06709400	014C0885	20009400	00271084

7.7 Table 6. Eta based products

The three tables below list products that are generated from Eta model output as of June 1993. Table 6.1 lists specific Eta replacements of LFM–based graphics and bulletins. Table 6.2 lists Eta based facsimile products. Table 6.3 lists the stations for which FOUS 60–78 bulletins are generated from Eta model output.

Table 6.1 LFM based products replaced by Eta based products as of June 1993

WMO or AFOS product label	Forecast hours covered	Product users
Surface to 500 mb lifted index (INL)	00 hour forecast	AFOS, AGS
850 mb geopotential height (graphics – 826,846,866)	12–36 hour forecasts	AFOS, AGS
850 mb temperature (828,848,868)	12–36 hour forecasts	AFOS, AGS
LFM look–alike 0.33–1.00 layer mean relative humidity (I25,I45,I65)	12–36 hour forecasts	AFOS, AGS
NMC standard sea level pressure (024,044,064,084)	12–48 hour forecasts	AFOS, AGS
500 mb geopotential height (526, 546, 566, 586)	12–48 hour forecasts	AFOS, AGS
500 mb absolute voriticity (527, 547, 567, 587)	12–48 hour forecasts	AFOS, AGS
1000–500 mb thickness (K23, K43, K63, K83)	12–48 hour forecasts	AFOS, AGS
700 mb vertical velocity (7UV, 7WV, 7YV, 7ZV)	12–48 hour forecasts	AFOS, AGS
FOUS 40–43 KWBC (FOH 40–43)	12–48 hour freezing level forecasts	AFOS, USAF, ISPAN WMSC, AWIPS
FRH guidance (FOUS 60–78 KWBC FRH 60–78)	00–48 hour direct model, output guidance	AFOS, DOD, CANADA, ISPAN

Table 6.2 Eta based facsimile products.

San Juan facsimile circuit:

Slot number	Product description
J038	12hr 700 mb height and relative humidity 12hr total accumulated precipitation and 700 mb vertical velocity 12hr 500 mb height and vorticity 12hr mean sea level pressure and 1000–500 mb thickness

Slot number	Product description
J039	24hr 700 mb height and relative humidity 24hr total accumulated precipitation and 700 mb vertical velocity 24hr 500 mb height and vorticity 24hr mean sea level pressure and 1000–500 mb thickness
J040	36hr 700 mb height and relative humidity 36hr total accumulated precipitation and 700 mb vertical velocity 36hr 500 mb height and vorticity 36hr mean sea level pressure and 1000–500 mb thickness
J044	48hr 700 mb height and relative humidity 48hr total accumulated precipitation and 700 mb vertical velocity 48hr 500 mb height and vorticity 48hr mean sea level pressure and 1000–500 mb thickness

Alaska facsimile circuit:

Slot number	Product description
A070	12hr 500 mb height and vorticity 24hr 500 mb height 36hr 500 mb height and vorticity

Difax facsimile circuit:

Slot number	Product description
D024	00hr 500 mb height and vorticity (00Z) 12hr 500 mb height and vorticity 24hr 500 mb height and vorticity 36hr 500 mb height and vorticity
D154	00hr 500 mb height and vorticity (12Z) 12hr 500 mb height and vorticity 24hr 500 mb height and vorticity 36hr 500 mb height and vorticity
D034	FDFAX LFM FAXPLOT (point plots of model winds and temperatures) (00Z)
D169	FDFAX LFM FAXPLOT (12Z)

Table 6.3 FRH station list for Eta–based direct model output guidance

PIL	Stations	WMO header	Distribution
FRH60	9B6 AFA BGR CAR CON PWN	FOUS60 KWBC	AFOS (E,C), DDS, USAF WMSC, CANADA, ISPAN
FRH61	ALB BOS BTV IPT LGA PHL	FOUS61 KWBC	AFOS (E,C) DDS, USAF, WMSC, CANADA, ISPAN
FRH62	C7H DCA HAT ILM ORF RDU	FOUS62 KWBC	AFOS (E,S,C), DDS, USAF, WMSC, ISPAN
FRH63	3J2 CAE LAL MIA SAV TLH	FOUS63 KWBC	AFOS (E,S,C), DDS, USAF, WMSC, ISPAN
FRH64	BUF CLE CRW DAY IND PIT	FOUS64 KWBC	AFOS (E,S,C), DDS, USAF, WMSC, CANADA, ISPAN
FRH65	ATL BNA MEM SDF STL TYS	FOUS65 KWBC	AFOS (E,S,C), DDS, USAF, WMSC, ISPAN
FRH66	BHM JAN LIT MOB MSY SHV	FOUS66 KWBC	AFOS (S,C), DDS, USAF, WMSC, ISPAN
FRH67	DTW INL MKE MSP ORD SSM	FOUS67 KWBC	AFOS (E,C), DDS, USAF, WMSC, CANADA, ISPAN,
FRH68	BFF DDC DSM LBF OMA TOP	FOUS68 KWBC	AFOS (S,C), DDS, USAF, WMSC, ISPAN
FRH69	BRO DFW DRT IAH OKC SAT	FOUS69 KWBC	AFOS (S,C), DDS, USAF, WMSC, ISPAN
FRH70	BIL BIS FSD GTF MSO RAP	FOUS70 KWBC	AFOS (E,C), DDS, USAF, WMSC, CANANDA, ISPAN
FRH71	ABQ CYS DEN ELP LBB PHX	FOUS71 KWBC	AFOS (S,C,W), DDS, USAF, WMSC, ISPAN
FRH72	BOI GEG MFR PDX PIH SEA	FOUS72 KWBC	AFOS (C,W), DDS, USAF, WMSC, CANADA, ISPAN
FRH73	CDC FAT LAX RNO SFO SLC	FOUS73 KWBC	AFOS (S,C,W), DDS, USAF, WMSC, CANADA, ISPAN
FRH74	YLH YMW YOW YQB YQT YYB	FOUS74 KWBC	AFOS (C,E), DDS, USAF, WSMC, CANADA, ISPAN
FRH75	YEG YPA YQD YQR YWG YYC	FOUS75 KWBC	AFOS (C,W), DDS, USAF, WMSC, CANADA, ISPAN
FRH76	MCD YCG YRV YVR YXC YXS	FOUS76 KWBC	AFOS (W), DDS, USAF, WMSC, CANADA, ISPAN
FRH77	G2GFA G2GFB G2GFC G2GFD G2GFE G2GFF	FOUS77 KWBC	AFOS (S), DDS, USAF, WMSC, ISPAN
FRH78	EDW UCC X68 BTNM3 LGIN6 LWS	FOUS78 KWBC	AFOS (E,S,C,W), DDS, USAF, WMSC, ISPAN

Appendix 2: Using the Eta Post Processor

8.1 Introduction

In this appendix we discuss in greater detail how to use the Eta post processor. We assume the reader knows how to run the Eta model. The peculiarities of any single user application necessarily limits how specific our treatment can be. It is hoped enough information is given to get the reader started using the Eta post processor.

8.2 Namelist FCSTDATA

Prior to running the model the user must set variables in namelist FCSTDATA accordingly. We draw attention only to those variables in FCSTDATA which impact the post processor. These are TSTART, TEND, TPREC, NMAP, TSHDE, and SPL. The model integration starts at hour TSTART and runs through hour TEND. Total and convective precipitation are accumulated over periods TPREC hours long starting from hour TSTART. The times (measured in hours) at which to post model fields are set in array TSHDE. NMAP is the number of posting times specified in array TSHDE. Currently the maximum number of posting times is forty–nine. The only restriction on the output times is that they be between TSTART and TEND. Note that the accumulation of precipitation over TPREC hour intervals operates independently of the posting times set in TSHDE. The last variable of interest to the post processor in namelist FCSTDATA is array SPL. Through this array the user sets the standard pressure levels (in Pascals) to which the post will be able to interpolate data. We postpone discussion of how the pressures in SPL are interpreted by the post processor to the next section.

8.3 The Control File

The user interacts with the post processor through a control file. The set–up of this file is similar to one used with the NGM. By editing the control file the user selects which fields to post, what grid to post the fields to, and what format to output the fields in. If fields are to be posted to a grid other than the model grid interpolation weights may be computed beforehand and read in. Depending on the number of output fields, calculation of interpolation weights can require more CPU time than the time it takes to post the fields. Obviously, operational Eta runs utilize pre–computed interpolation weights. However, this is not necessary. The post retains the ability to compute interpolation weights itself prior to posting fields. By stringing together several control files the user may request that the same or different fields be posted on different output grids. In turn, these different grids may be in the same or different output files.

The simplest way to describe the control file is by means of an example. Below is a portion of the operational

```
KGTYPE*******I5*******:(00104)***********START OF THIS OUTPUT GRID*****
DATSET     *A6*     :(ETA_XP)
OUTFILE    *A6*     :(PACK84)
NUFILE     *A6*     :(YES)
  POLA     *L1*     :(TTTTT)
  NORTH    *L1*     :(TTTTT)
  IMOUT    *I5*     :(00147)
  JMOUT    *I5*     :(00110)
  POLEI    *F11.6*  :(0075.500000)
  POLEJ    *F11.6*  :(0109.500000)
  ALONVT   *F11.6*  :(0105.000000)
  XMESHL   *F11.6*  :(0090.754640)
  READLL   *A6*     :(NONE  )
  READCO   *A6*     :(YES   )
(PRESS ON ETA SFCS  )  Q=(    8),  S=( 148),   SMTH=(00 00 00)
L=(00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000)
 ...
(HEIGHT OF PRESS SFCS)  Q=(    1),  S=(   8),   SMTH=(00 02 02)
L=(11111111111111111111 00000 00000 00000 00000 00000 00000 00000 00000)
(TEMP ON PRESS SFCS )   Q=(   16),  S=(   8),   SMTH=(00 02 02)
L=(11111111111111111111 00000 00000 00000 00000 00000 00000 00000 00000)
...
(NGM 0.85-1.00 QCONVG ) Q=(  103),  S=( 148),   SMTH=(00 03 03)
L=(10000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000)
****DONE WITH THIS GRID***
 KGTYPE*******I5*******:(99999)******START OF THIS OUTPUT GRID*****
 DATSET     *A6*     :(ETA_XP)
 OUTFILE    *A6*     :(PACK84)
 NUFILE     *A6*     :(NO )
   POLA     *L1*     :(TTTTT)
 ...
 ***DONE WITH THIS GRID***
```

Fig. A1. Portion of control file from the operational Eta model.

Eta control file. A control file consists of three basic components: the header, body, and end mark. In the header the user sets the output grid type, the data set name, the data format, a new file flag, output grid specifications, and two additional input/output flags. Following the header the user specifies which fields and levels to post. The post processor has a fourth order smoother and a 25 point Bleck filter through which data may be passed. By setting integer switches in the body the user controls these features. The order in which the post processes requested output fields is fixed by the code but the order in which the user requests the fields is immaterial. The body of a control file only needs to list those fields the user wants. To allow for this flexibility every control file must end with an end mark. The end mark line tells the post processor to stop reading the control file and start posting requested fields.

At first glance the header block of a control file appears confusing. The key to understanding the header is remembering what the variable name at the start of each line means. `KGTYPE` is a nonnegative integer representing the type of output grid. The convention here is to use Office Note 84 grid types with two exceptions. The first exception is shown at the bottom of Fig. A1. Grid type `99999` is the staggered E grid, regardless of the horizontal resolution. The second exception is grid type `00000`. This grid type instructs the code to post the requested field(s) on a filled E grid. In the upper portion of Fig. A1 grid type 104 is the NGM "super–C" grid. The string "`START OF THIS OUTPUT GRID`" is simply added for readability. The post processor ignores everything in the header outside of the parentheses. Each line of the header contains the data format the post expects to read. Proper spacing is **crucial**. `DATSET` is the root from which the post generates output filenames. To this root the post appends the forecast hour (e.,g., `ETA_XP00`, `ETA_XP06`, etc.). Via the character string `OUTFILE` the user specifies the format of the posted data. Currently two data formats are available: unpacked (Cray) binary and Office Note 84. Setting `DATSET` to `NOPACK` tells the post to write data using unformatted FORTRAN writes. A short program is available from the author to convert Cray binary to other binary formats using the UNICOS assign statement. With `DATSET` = `PACK84` an Office Note 84 packed data set is generated. At a later date the ability to post data directly in GRIB will be added. Currently a program on the NAS 9000 converts Office Note 84 packed data sets to GRIB1. Variable `NUFILE` allows the user to specify whether fields requested in the body are to be appended to a currently open output file or if a new output file is to be opened. It is a simple `YES` or `NO` switch.

The indented variables in the header deal with the output grid and pre–computed interpolation weights. `POLA`, `NORTH`, `IMOUT`, `JMOUT`, `POLEI`, `POLEJ`, `ALONVT`, and `XMESHL` are the basic set of parameters by which standard NMC software defines polar stereographic grids. `POLA` and `NORTH` are logical flags. Setting both to true `(TTTTT)` specifies a polar stereographic projection in the northern hemisphere. (`IMOUT`, `JMOUT`) are the number of west–east and south–north grid points (directions relative to the rotation specified by `ALONVT`). Grid point (1,1) is in the southwest corner of the grid; (`IMOUT`, `JMOUT`) in the northeast corner. `POLEI` and `POLEJ` define the floating point (i,j) location of the pole point with respect to the output grid. `ALONVT` is the longitude (west longitude being positive) from which grid east and north are defined. Finally, XMESHL is the grid spacing in kilometers. Via these eight parameters all standard polar stereographic NMC grids may be specified.

The user may sidestep this method to define an output grid by setting READLL to YES. This tells the post to read an input file containing the geodetic latitude (glat) and longitude (glon) of output grid points. The post can read multiple (glat, glon) files starting from unit number 30. The structure of the (glat, glon) file expected by the post is (((glat(i,j),glon(i,j)),i=1,imout),j=1,jmout) using FORMAT 5(g12.6,1x). A word of caution. This option of the post has not been exhaustively tested since most users desire data on standard polar stereographic NMC grids.

The last entry in the header block tells the post if pre–computed interpolation weights are available. Performance timings showed that by far the largest percentage of CPU time executing the post was in computing interpolation weights. If READCO is NONE the post computes all necessary interpolation weights once and then proceeds with the posting. Having the post compute interpolation weights frees the user of this burden and adds generality to the post. However, for repeated runs it is wise to compute the weights beforehand. (Source is available from the author to compute these weights.) With READCO set to YES the post reads weights starting from unit 20. If the control file has several output grids the unit number for the weights increments by one for each output grid up to a maximum unit number of 29. The user must ensure that the order in which interpolation weights are assigned is the order in which the grids are listed in the control file (see Section 8.4 for elaboration).

The bulk of the control file is the body. This is where the user specifies which fields to post and optionally the degree of smoothing or filtering to apply to the posted fields. There are currently 110 unique fields that may be posted from the Eta model. This, of course, is subject to change in response to model development and user needs. As mentioned above it is not necessary to list all 110 available fields in the body of the control file. Only those fields which are desired need to be listed. Each field specification consists of two lines. The first line, the identifier line, starts with a brief description of the field. The post processor ignores this. Following this are blocks Q=(xxx) and S=(xxx). The Q and S refer the first and second entries of the 27 element Office Note 84 label. In any copy of the control file obtained from the author these labels are properly set.

The SMTH block on the identifier line controls the smoothing or filtering. In most applications the model to output grid process involves two steps. First the staggered E grid is filled to make a regular grid. This is then interpolated to the output grid. Multiple pass smoothing or filtering of the data may be activated at any of three places in this process. The first element of the SMTH block activates a fourth order smoother that works on the staggered E grid. A positive, nonzero integer tells the post to apply this smoother to the field the indicated number of times. A more heavy handed multiple pass smoother was found necessary to produce pleasing vorticity fields. Thus when smoothing a vorticity field it is this smoother, not the fourth order smoother, that is applied. Once data are on a regular grid a 25 point Bleck filter may be applied. This may be done in two possible places. The second integer segment in the SMTH block controls the filtering of data on a filled E grid. The last integer block of SMTH activates the Bleck filter on the output grid. The Bleck filter is designed to remove scales smaller than twice the grid separation. It has a fairly sharp response curve and will largely preserve field maxima and minima even with several applications.

Following the identifier line is the level line (L=) where the user requests data on particular levels. There is room for output on as many as sixty levels. Some fields (e.g., total precipitation, shelter temperature, tropopause pressure) are single level fields. For single level fields the integer 1 in the place immediately following the left parenthesis activates output of the field. In general the integer 1 activates output at a given level; 0 turns off output at that level. However, there are exceptions which are noted below.

For isobaric fields (fields for which S=8) the pressure levels to which data may be posted are controlled by namelist FCSTDATA read in at the start of an Eta model integration. Standard Eta model runs post data to 19 pressure levels from 100 to 1000 mb (50 mb intervals). Moving left to right across the level line are pressure levels 100, 150, 200, 250, ..., 950, and 1000 mb. Fields may be posted to different pressure levels by editing namelist FCSTDATA. The point to remember is that the order in which pressure levels are specified in FCSTDATA maps directly to the left to right ordering of integers on the level line.

As an example consider the lines

```
(HEIGHT OF PRESS SFCS    ) Q=(     1),  S=(    8),  SMTH=(00 02 02)
L=(11111 11111 11111 11110 00000 00000 00000 00000 00000 00000 00000 00000)
```

from Fig. A1. The field is geopotential height on isobaric surfaces The Q and S integers are set for Office Note 84 packing. For each requested level two passes of the the Bleck filter will be applied to data on the filled E grid and the output grid. Heights at 100, 150, 200, 250, ..., 1000 mb will be posted.

For data on constant eta layers two options are available. Setting the n–th integer on the level line to 1 instructs the post to extract data on eta layer n. Note that the vertical numbering convention in the Eta model is top down. That is, layer one is at the top of the model with the vertical index increasing downward. At times it may be of interest to see what a selected field looks like in the n–th atmospheric eta layer. This is a terrain following perspective. To activate this option set the n–th integer (left to right) on the level line to any integer between 2 and 9, inclusive. For example, if a user wanted pressure data on the first, second, and fourth atmospheric eta layers the specifications could look like

```
(PRESS ON ETA SFCS     )  Q=(     8),  S=( 148),   SMTH=(00 00 00)
L=(22020 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000)
```

In addition to eta layer and isobaric level data multiple levels may be requested for FD fields and boundary layer fields. There are six FD levels. The ordering on the level line is from lowest to highest FD level. Boundary layer fields are available from six 30 mb deep layers. The ordering on the level line is from the lowest (nearest the surface) to the highest constant mass layer. All other fields are single level. That is, the leftmost integer activates (1) or deactivates (0) posting of that field.

The last section of a control file is the end mark. This single line tells the post processor to stop reading the control file and start posting requested fields. The key word on the line is DONE. The post scans each line read from the control file for this string. It is the only way to specify the end of a control file.

As shown in Fig. A1 individual header–body–end control files may be chained together to output data in numerous ways. The post reads the control files sequentially. If pre–computed interpolation weights are to be read in the user must ensure that their assigned unit numbers correspond to the order in which the grids appear in the combined control file. One last detail involves the end mark at the end of the last control file. The post knows it has processed everything when it reads an end of file mark (EOF) from the control file. This EOF must immediately follow the last DONE statement. If not, the post will unsuccessfully try to process what it thinks is the next set of control cards.

8.4 The Template

If the post is to be run externally from the model the user must provide the model a "blank" template. The template is a script which sets the stage for running the post, runs the post, and then cleans up after running the post. The model reads and edits this template during the integration at posting times specified by the user through namelist FCSTDATA. It is possible for the model to submit post jobs to batch queues during its execution. This option is rarely exercised due to the near saturation of the Cray. Rather, external posting is done after model integration within the same batch job. In this case the edited templates are simply executed as shell scripts. Quasi–operational parallel Eta runs use this approach. When running the post processor internally a template is not required. Instead, pre–post job set up and file assignments must be included in the script running the Eta model. The operational Eta uses an internal post. Figure A2 below is the template used for quasi–operational Eta runs.

```
#***************** Script to run Eta Post Processor ********************
#   As the model runs it edits this script.  Specifically it replaces
#   the string xx with a unique two digit integer tag.  Doing so permits
#   the model to continue running regardless of the status of post jobs.
#
#    Below are Cray Unicos commands to submit a batch job.  The leading #
#    is part of the command.  These lines are only required if the post
#    is to be run as its own batch job.
#QSUB -r wwepost -q para2
#QSUB -lM 24Mw -lT 200
#QSUB -eo
#QSUB
#-----------------------------------------------------------------------
#   Initial setup.
ASSIGN=.asgnxx
FILENV=$ASSIGN
NCPUS=1
export FILENV NCPUS
#-----------------------------------------------------------------------
#   Set environment variables for temporary files.
TMPOMG=tmpomgxx
TMPOUT=tmpoutxx
#-----------------------------------------------------------------------
#   Copy control file and weights to working directory. This step is
#   done in the quasi-operational parallel eta jobstream.  Running the
#   post as a separate batch job would require these or similar copies.
#cp /wd2/wd20/wd20rt/eta/etapost/etapost_eta        control_file
#cp /wd2/wd20/wd20rt/eta/etapost/e2gd/wgt_exp_g104  interp_wgts1
#cp /wd2/wd20/wd20rt/eta/etapost/e2gd/wgt_exp_g026  interp_wgts2
#cp /wd2/wd20/wd20rt/eta/etapost/e2gd/wgt_exp_g101  interp_wgts3
#cp /wd2/wd20/wd20rt/eta/etapost/e2gd/wgt_exp_g104  interp_wgts4
#cp /wd2/wd20/wd20rt/eta/etapost/e2gd/wgt_exp_g005  interp_wgts5
#cp /wd2/wd20/wd20rt/eta/etapost/lastjob            lastjob
#cp /wd2/wd20/wd20rt/eta/etapost/etapost.x          etapost.x
#-----------------------------------------------------------------------
#   Assign the input/output files.  Unit 4 is the control file.  Runtime
#   output is written to unit 6.  The post processor reserves unit 7
#   temporary file TMPOMG, 8 for TMPOUT.  Interpolation weights are read
#   from units 20 through 29.  User defined (lat,lon) grid(s) are read
#   from units 30 through 39.  Gridded output files start with unit
#   number 40.
assign -a control_file   fort.4
assign -a runtime_output fort.6
assign -a $TMPOMG        fort.7
```

```
assign -a $TMPOUT        fort.8
assign -a interp_wgts1   fort.20
assign -a interp_wgts2   fort.21
assign -a interp_wgts3   fort.22
assign -a interp_wgts4   fort.23
assign -a interp_wgts5   fort.24
#-----------------------------------------------------------------------
#   Run the post processor.
etapost.x
#-----------------------------------------------------------------------
#   Clean up after the posting job.
rm $TMPOMG $TMPOUT $ASSIGN core
#-----------------------------------------------------------------------
#   If running the post as a batch job the user might want to trigger a
#   sequence of jobs after the last set of fields are posted.  This is
#   not done for quasi-operational parallel Eta runs.
#LAST="sh lastjob"
#$LAST
#rm lastjob
#-----------------------------------------------------------------------
#   End of output job.
exit
```

Fig. A2. Template for quasi–operational parallel Eta model runs.

8.5 Pre–computed Interpolation Weights

For many single or limited use applications it is not necessary or worthwhile to pre–compute interpolation weights. The post will automatically compute these weights when the flag READCO=NONE. For repeated model runs using the same model grid and output grids considerable time savings can be realized if pre–computed weights are read in at the start of each post execution.

Source code is available from the author to pre–compute all necessary interpolation weights. All that is required are the Eta model grid specifications and those for the output grid or grids. These specifications are set in namelists. For most grids the job to pre–compute interpolation weights can be run interactively on the Cray.

8.6 Internal and External Post

Mention has already been made of the various modes in which the Eta post processor can be run; further elaboration follows. In the early stages of development it was envisioned that the post processor would run as stand–alone code external to the model. The model would spawn post jobs as it ran. The complexities of Cray queuing priorities and scheduling, the near saturation of the Cray, and the time constraints of operational forecasting necessitated a version of the post that runs within the Eta model. Care has been taken to ensure consistency between internal and external versions of the post processor. Virtually all aspects remain the same between the two except for some subtle programming details.

In the internal mode pre–post job steps and file assignments must be made in the script running the Eta model. This removes the need for a template. Data required by the post is passed via commons. For the operational Eta a batch job is spun off every twelve hours of model integration to dispose posted fields to the NAS 9000 for graphics generation and dissemination. The size of the combined model–post executable precludes its use for non–operational model runs.

In the external mode the model edits a template at it runs. This template runs the post as discussed above. Prior to editing the template the model dumps virtually all model variables in commons to temporary output files named `TMPOMGxx` and `TMPOUTxx`. Creation of these temporary files allows the post to run externally regardless of status of the model integration. Immediately upon termination of each post executable the used temporary files are removed. The temporary files can be huge (`TMPOUTxx` is 60 Mb for the operational Eta domain). The user should ensure that sufficient `/tmp` disk space is available under their user quota prior to submitting the model run. For most applications this is not a problem.

Other than these brief remarks the variability from one user application to the next precludes a more detailed discussion of how to set up the model and post. Sample scripts are available from the author which illustrate various model–post configurations.

8.7 Summary

In this appendix we have described how to use the Eta post processor in conjunction with the model. The post processor can be run either internal or external to the model. Most users will run the post externally after model execution but within the same batch job. This necessitates a template which the model edits as it runs. The user controls the post by editing a control file. In this file the user specifies the fields to post, smoothing, data format, and output grids. This is common to all versions of the post. Both internal and external versions of the post may read pre–computed interpolation weights.

Further details beyond those given get into the specific needs of each user. Sample scripts and assistance are available from the author.