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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
NATIONAL CENTER FOR ENVIRONMENTAL PREDICTION

OFFICE NOTE XXX

THE NCEP ETA MODEL POST PROCESSOR: A DOCUMENTATION

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AMONG NCEP STAFF MEMBERS

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1. Introduction

This Office Note describes the post processor for the National Center for Environmental Prediction 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. Details for using the post processor in conjunction with the model are found in Appendix 1. Appendix 2 lists the various NCEP data sets from which operational Eta model output is available.

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 Phillips (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 non cancellation 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,

$$\eta = \frac{p - p_t}{p_s - p_t} \times \eta_s, \tag{2.1}$$

where

$$\eta_s = \frac{p_{rf}(z_s) - p_t}{p_{rf}(0) - p_t}. \tag{2.2}$$

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 $\eta = 1$ case of the eta coordinate. The reference pressure used in the Eta model is $p_{rf}(z) = p_{rf}(0)((T_0 - \Gamma Z)/T_0)^{\beta}$, where $p_{rf}(0)$ = 1013.25mb, To = 288K, $\Gamma = 6.5^{\circ}/(\mathrm{km})$, $\beta = (R\Gamma)/g$, g=9.8 m/s^2, and R = 287.04J/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 50N and 111W for the current operational Eta with 22 km resolution. Two rotations are involved. One moves the Greenwich meridian to 111 W. 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 22 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 blond boundary conditions with values in the computational domain. The boundaries are one way interactive.

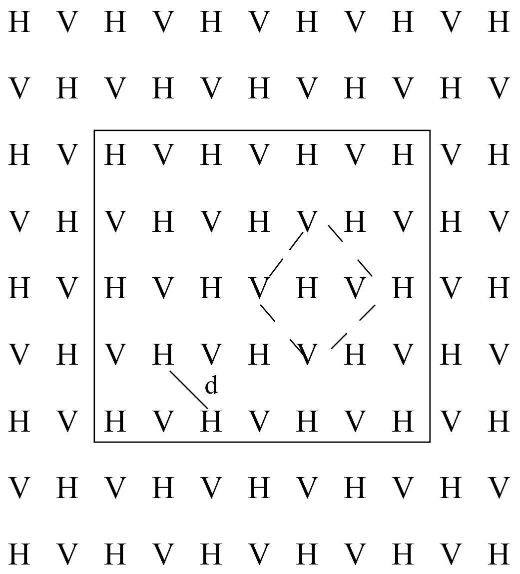


Fig. 1. Arakawa E grid of Eta model. H denotes mass points, V velocity points. The solid box outlines the computational domain. The dashed box represents a model step.

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.

The operational Eta runs with 38 vertical layers. The thickness of the layers varies with greatest vertical resolution near sea level and around 250mb (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, minimize this effect.

Model variables are staggered vertically as well as horizontally (Fig. 2). 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. 2.

The model uses a technique for preventing grid separation (Mesinger 1973, Janjic 1974) in combination with the split-explict time differencing scheme (Mesinger 1974, Janjic 1979). The fundamental time step for the 22 km operational Eta model is 60 seconds. This is the mass-momentum adjustment time scale. Advection, physical processes, and cumulus convection 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 (Janjic, 1984). Vertical advection of moisture is based on the piecewise-linear method (Carpenter et aL, 1989).

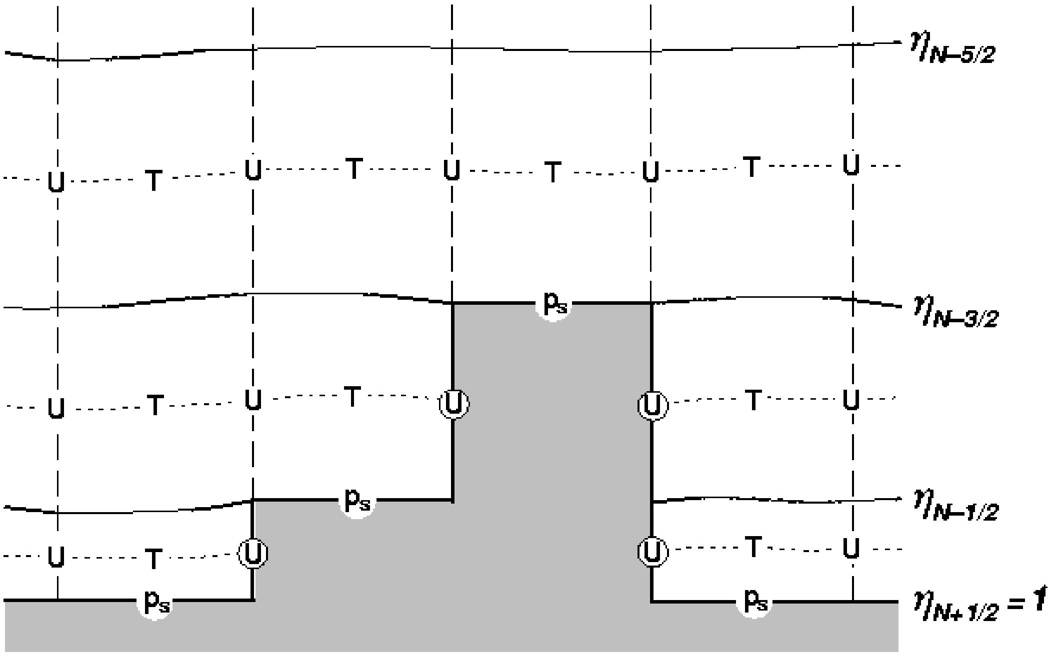


Fig. 2. Vertical cross section through Eta model with N layers. Mass variables such as temperature and momentum variables such as zonal wind components (T and U respectively) are defined at the midpoint of each eta layer. P_s is the surface pressure. The circled wind components along the side of steps are identically zero as specified by the no-slip boundary used in the model.

The model includes a fairly sophisticated physics package (Janjic, 1990, 1994) consisting of the Mellor and 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 uses 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), Betts and Miller (1986), and Janjic (1994). The radiation is the NCEP version of the GFDL radiation scheme with interactive random overlap clouds.

The operational Eta runs from an analysis based on the regional 3-d variational analysis (3DVAR). First guess for the Eta forecast comes from the Eta-based data assimilation system (EDAS). Fully cycled EDAS has been used to generate better initial conditions that requires less time for spinup. Boundary conditions for the model are provided by 6 hour old aviation forecasts.

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

Various changes have been made to the Eta post processor since the codes were first written in 1992. These changes include debugging, adding more posted fields, converting from 1-D indexing to 2-D indexing, paralleling codes to run on multiple CPU, and modifying the post to process output from both eta and sigma modes. The parallelization of the Eta post processor not only reduces the time it takes to process data but also enables the Eta post to handle domain with larger dimensions.

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.

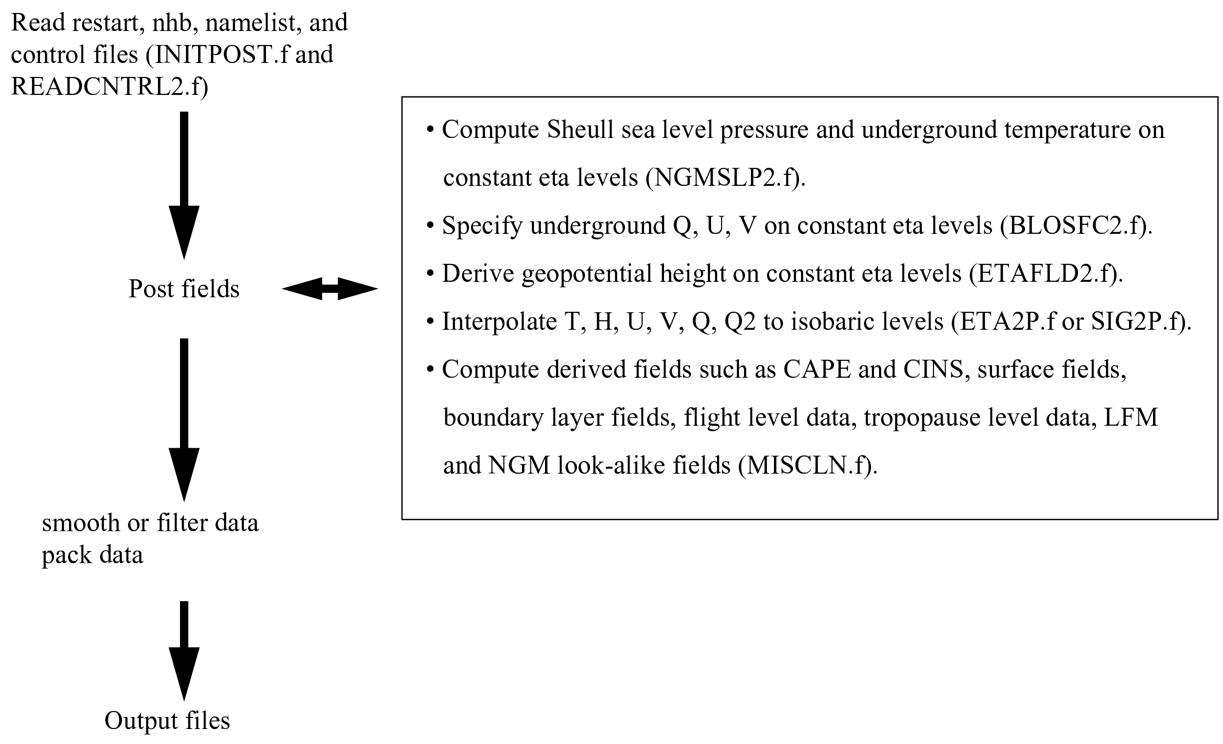
With these purposes in mind the Eta post processor was designed to be modular, flexible, and relatively easy to use. A modular approach allows easy introduction of new routines to compute new output fields or test improved algorithms for currently posted fields. The post processor can run internal or 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 is posted in GRIB format.

Data maybe posted on the staggered E grid, a filled (i.e., regular) version of this grid, or any grid defined using standard NCEP 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, which is completed in the product generator, 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 3 charts this ordering. Our discussion of the post processor in the Section 4 follows this flowchart.



- Compute Sheull sea level pressure and underground temperature on constant eta levels (NGMSLP2.f).
- Specify underground Q, U, V on constant eta levels (BLOSFC2.f).
- Derive geopotential height on constant eta levels (ETAFLD2.f).
- Interpolate T, H, U, V, Q, Q2 to isobaric levels (ETA2P.f or SIG2P.f).
- Compute derived fields such as CAPE and CINS, surface fields, boundary layer fields, flight level data, tropopause level data, LFM and NGM look-alike fields (MISCLN.f).

Fig. 3. Schematic of flow through post processor.

The Eta post processor is now also able to process the output of the Eta model forecast in sigma mode. There are two options in processing sigma output. The first option interpolates standard model output fields from sigma to pressure coordinates using traditional bilinear interpolation. The second option uses cubic spline fitting method when performing vertical interpolation. The computation of sea level pressure has been migrated from within the post processor to within the Eta quilt because the sounding post that runs parallel to the main post processor needs sea level pressure as input from the restart files. The sounding post generates the sounding profile. Besides the Sheull and Messinger sea level pressure reduction, the addition of processing sigma restart files using spline method results in the third option of deducing sea level pressure in the sigma mode. A logical switch, SPLINE, was put in the namelist fcstdata.parm which is read in by both Eta quilt and eta post processor. When SPLINE is set to TRUE, the spline fitting method would be used to perform vertical interpolation while the bi-linear interpolation method would be used when SPLINE is set to FALSE. The outcome of the two methods does not appear to be very different for the fields above the ground. However, the underground fields and sea level pressure field were slightly more smooth when using the spline fitting method. Additionally, the locations of the cyclone centers were also slight different with different sea level reduction methods.

4. The Eta Post Processor - Details

The following subsections 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 Constant eta and pressure fields

One can 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 stream function, and turbulent kinetic energy. Pressure may also be posted on constant eta layers.

Two options exists 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. 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 height field on the eta interfaces is not one of the output variables from model forecast and therefore needs to be calculated in the post. The interfaces that overlap with the eta terrain were specified to be the terrain height. The heights above the ground on each eta interface is then integrated using temperature and specific humidity on the eta mid-layers based on hydrostatic relationship.

The more traditional way of viewing model output is on constant pressure surfaces. The post processor interpolates fields to thirty-nine isobaric levels (every 25 mb from 50 to 1000 mb). Vertical interpolation of height is quadratic in log pressure. For temperature, specific humidity, vertical velocity, horizontal winds, and turbulent kinetic energy, the vertical interpolation is linear in log pressure. Derived fields (e.g., dewpoint temperature, relative humidity, absolute vorticity geostrophic stream function, etc.,) are computed from vertically interpolated base fields.

The following methods are used to obtain the fields on the isobaric levels that lie above the model top (currently 25 hPa). Vertical and horizontal wind components above the model top are specified to be the same as those at the uppermost model level. For isobaric levels below the lowest model layer the first atmospheric eta layer (e.g., the first eta mid-layer above the ground) 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 first and the second interfaces above ground interfaces.

Temperature, humidity, cloud/ice water, and geopotential heights are treated differently. The temperature averaged over the two uppermost model layers is used as the temperature on all the pressure levels above the model top. The specific humidity at the target level is set so as to maintain the relative humidity averaged over the two uppermost model layers. The cloud/ice water on the isobaric levels above the model top is specified as the cloud/ice water on the model top. Geopotential heights on isobaric surfaces 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. This is because including data from the first atmospheric layer imposed a strong surface signature on the extrapolated isobaric level data.

The treatment for the fields that are underground but above the lowest model layer is very similar to the treatment for fields below the lowest model layer. The further detail will be described in the section 4.3.

4.2 Sea level pressure

4.2.1 Eta mode

Sea level pressure is one of the most frequently used fields posted from any operational model. Because over large portions of the Eta Model domain is below the model terrain, some assumption has to made to obtain sea level pressure at a underground grid point. Although there is no one best way to specify the underground sea level pressure as well as other underground fields, it is desirable to specify these fields so that they are representable and somewhat smooth. Although, as mentioned previously, the computation of sea level pressure is now carried out in the Eta Quilt instead of Eta Post, the computation of sea level pressure will still be discussed here for completeness. 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

$$\frac{dz}{-d(\ln p)} = \tau = \frac{R_d T_v}{g}, \tag{4.1}$$

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,

Rd = dry air gas constant, and

g = gravitational acceleration.

Mean sea level pressure, *pmsl*, is computed at mass points using the formula $p(msl) = p(sfc) \times e^{f}$. The function $f = \tau^{*}/z(sfc)$, 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 $\tau_{cr} = R_d/g \times 290.66$.

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 $\mu = 0.005 \times g/R_d$.

Once mean sea level pressure is computed, a consistent 1000 mb height field is obtained using the relation $p(\mathrm{msl}) - p(1000\mathrm{mb}) = \rho^* \times z(1000\mathrm{mb})$. 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 τ^* 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. He made a assumption that sea level pressure should be obtained to maintain the shape of the isobars on surfaces of constant elevation. Therefore, 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 T_v on each step inside the mountain (i.,e., underground) are obtained by solving a Laplace equation:

$$\nabla^2 T_v = 0 . \tag{4.2}$$

Atmospheric virtual temperatures on the same step surrounding the mountain provide consistent, realistic boundary conditions. The relaxation method is used to smooth the virtual temperature on all the grid points. However, only the underground virtual temperature is replaced by the smoothed virtual temperature. In the Eta Post, (4.2) is solved by applying an eight-point averaging to the virtual temperature fields on each eta mid-layer:

$$\begin{aligned}T_v(i, j) = {} & A \times (4 \times (T_v(i + ihw(j), j - 1) + T_v(i + ihe(j), j - 1) \\ & + T_v(i + ihw(j), j + 1) + T_v(i + ihe(j), j - 1)) \\ & + T_v(i - 1, j) + T_v(i + 1, j) + T_v(i, j - 2) + T_v(i, j + 2) \quad , \\ & - B \times T_v(i, j)\end{aligned} \tag{4.3}$$

where A and B are constants, and ihw and ihe are increments in *i* directions for the grid points that are on the west and east of the grid point (i,j). Currently, the eight-point averaging is applied to the virtual temperature fields 500 times. Once all underground temperatures have been generated the hydrostatic equation (e.g., (4.1)) is integrated downward to obtain sea level pressure. Note that the thickness *dz* used to calculate the sea level pressure are not the actual geopotential heights but the heights of the standard interfaces which are computed using standard ground level atmospheric temperature 288 K and standard lapse rate 6.5 K/km based on the hydrostatic relationship.

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 in the Eta mode. The standard and Mesinger schemes can produce 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.

4.2.2 Sigma mode

As mentioned previously, there are two options when processing the Eta model output in sigma mode, SPINE and NON-SPLINE, which then produces three different sets of sea level pressure.

Similar to Eta sea level pressure reduction, the first option generates sea level pressure using both Sheull and Mesinger reduction algorithms. Recall that the Messinger sea level reduction involves computation of eight-point averaging on constant eta levels. Therefore, because the sigma interfaces are often steep over the mountains, the temperature fields are first interpolated/ extrapolated from sigma to pressure vertical coordinates using the bi-linear interpolation/ extrapolation before the smoothing of the temperature fields is performed. The underground temperature is then obtained by solving Laplace equation of temperature on the constant pressure levels. All the other procedures used to obtain Mesinger sea level pressure are similar to those in the eta mode.

The procedures for generating sea level pressure using the second option: spline fitting method: are described as follows. First, the spline fitting method is used to interpolate height fields from sigma to pressure levels. Note that the spline fitting can only perform interpolation but not extrapolation. Therefore, when the lowest pressure level falls under the lowest sigma level over a specific grid point, the bi-linear extrapolation is done to obtain the height at the lowest pressure level. The sea level pressure at each grid point is then obtained by finding the pressure level at which height is equal to zero using the spline fitting method.

4.3 Subterranean fields

The treatment for the underground fields is very similar to the treatment for fields that are above the surface but below the lowest model layer as described in the section 4.1. The Horizontal wind components on the first atmospheric eta layer above ground are posted for all the pressure levels below the ground. The underground turbulent kinetic energy is specified as the average of the first and second layers above ground. The fictitious underground temperatures on the constant eta levels generated during deduction of Messinger sea level pressure were not used as output temperature for the Eta post. Instead, the underground temperature calculated during Sheull reduction is currently posted as underground temperature on the constant eta levels. Note that there is no underground fields on the constant sigma levels. The underground temperature on isobaric levels is then calculated using underground temperature on the constant eta levels or the average of the second and third layers above ground on the constant sigma levels bilinearly with respect to pressure. Underground specific humidity is adjusted to maintain the average of the second and third lowest atmospheric eta layer relative humidity.

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 three 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 field 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 minimize point maxima or minima in posted FD level wind fields. The 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 hPa 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). As coded in the post processor CAPE is the column integrated quantity (Cotton and Anthes 1989)

$$\mathrm{CAPE} = g\int_{\mathrm{lcl}}^{z^*}(\ln\theta_p - \ln\theta_a)dz \tag{4.4}$$

where,

θ_p = parcel equivalent potential temperature,

θ_a = ambient equivalent potential temperature,

Icl = 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 the equilibrium level, which is defined as the highest positively buoyant layer in the Eta post. During the lifting process positive area in each layer is summed as CAPE, negative area as CINS. Typical is Atkinson's (1981) definition of CAPE

$$\mathrm{CAPE} = g\int_{\mathrm{lcl}}^{z^*}\left(\frac{\theta_p - \theta_a}{\theta_a}\right)dz \tag{4.5}$$

with z^* being also 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 $\ln\theta_p - \ln\theta_a = \ln(\theta_p/\theta_a) = ((\theta_p - \theta_a)/\theta_a) - (1/2)((\theta_p - \theta_a)/\theta_a)^2 + \dots$, which shows the integrands to be related.

Posted CAPE values can indicate a greater potential for convection than may be realized. 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. This 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 990mb), 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 time-averaged stratiform and 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 pressure nor heights are posted from the operational Eta post.

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 in the fcstdata.parm file prior to the model run. 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 closure models. Assuming a horizontally homogenous surface layer at rest the Monin-Obukhov 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 $\zeta = z/L$. 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

$$\begin{aligned} U(z_2) - U(z_1) &= \frac{U^*}{x}\Phi_U(z_1, z_2, L) \\ \Theta(z_2) - \Theta(z_1) &= \frac{\Theta^*}{x}\Phi_U(z_1, z_2, L) \end{aligned} \quad . \tag{4.6}$$

where

L = Monin-Obukhov scale,

U^*, Θ^* = constant coefficients, and

x = von-Karman 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

$$\Phi_s(z_1, z_2, L) = \phi_s(0) \times \left[\ln\left(\frac{z_2}{z_1}\right) + \psi_s(\zeta_2) + \psi_s(\zeta_1)\right], \tag{4.7}$$

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

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.

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,

$$\sigma = \frac{p - p_t}{p_s - p_t}. \tag{4.8}$$

Given the pressure at the top of the model and the forecast surface pressure p_s, target sigma levels are converted to pressure equivalents. Vertical interpolation from the eta layer 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.

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
Rl (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
Tl (sigma layer 1 temperature)	NGM look-alike S1 temperature
T3 (sigma layer 3 temperature)	NGM look-alike S3 temperature

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

Fous 60-78 entry	Posted Eta field used
T5 (sigma layer 5 temperature)	NGM look-alike S5 temperature

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 LFM and identify appropriate sigma levels bounding LFM layer mean fields. The sigma levels used for layer mean relative humidities are 0.33 to l.00, 0.66 to l.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. 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: Using the Eta Post Processor

7.1 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.

7.2 Model and post processor source

Source for the most current operational eta post processor can be found in /nwprod/sorc/ eta_etapost.fd on the IBM. Source for the model forecast can be found in /nwprod/sorc/ eta_etafcst.fd. The makefile in each of the two directories is used to compile the post and forecast codes respectively to generate an executable. Both the post and forecast source codes have been parallelized to run on multiple processors. The use of multiple processors has made it possible to run the forecast and post the model output for domains with larger dimensions which could not have been accomplished by the serial code due to lack of memory space. Furthermore, the clock time needed to forecast and post Eta model is greatly reduced.

7.3 Namelist FCSTDATA

Prior to running the model the user sets runtime variables in namelist FCSTDATA. These settings affect both the model and the post processor. A sample FCSTDATA is shown in Fig. 8.1.

```
&FCSTDATA
TSTART=0.0,TEND=60.0,TCP=61.0,RESTRT=.TRUE.,SINGLRST=.TRUE.,
SUBPOST=.FALSE.,
NMAP=11,TSHDE=00.0,06.0,12.0,18.0,24.0,30.0,36.0,42.0,48.0,54.0,
          60.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,
          20.0,21.0,22.0,23.0,24.0,25.0,26.0,27.0,28.0,29.0,
          30.0,31.0,32.0,33.0,34.0,35.0,36.0,37.0,38.0,39.0,
          40.0,41.0,42.0,43.0,44.0,45.0,46.0,47.0,48.0,
SPL=5000.,7500.,10000.,12500.,15000.,17500.,20000.,22500.,25000.,
   27500.,30000.,32500.,35000.,37500.,40000.,42500.,45000.,
   47500.,50000.,52500.,55000.,57500.,60000.,62500.,65000.,
   67500.,70000.,72500.,75000.,77500.,80000.,82500.,85000.,
   87500.,90000.,92500.,95000.,97500.,100000.
NPHS=18,NCNVC=18,NRADSH=1,NRADLH=2,NTDDMP=1,
TPREC=12.0,THEAT=06.0,TCLOD=06.0,
TRDSW=06.0,TRDLW=06.0,TSRFC=06.0,
NEST=.FALSE.,SPLINE=.FALSE.
/
```

Fig. 7.1. Sample namelist FCSTDATA.

The model integration starts at hour TSTART and runs through hour TEND. If forecast is part of the dada assimilation cycle, then TCP is set to be equal to TEND and is the hour at which the restart file restrt03 is generated. When RESTART is set to true, then the model uses the full restart file as input initial condition. Otherwise, the Model initialized with nfc file. The times (measured in hours) at which to output forecast files are set in array TSHDE. NMAP is the number of posting times specified in array TSHDE. Currently the maximum number of posting times is ninety-nine. The only restriction on the output times is that they be between TSTART and TEND. Array SPL specifies isobaric levels (in Pascals) to which the post processor can vertically interpolate certain fields. The number of elements in array SPL is set by parameter LSM in include file parmeta. The ordering of pressure levels directly maps to level switches in the post processor control file. This will be covered later when we discuss the control file in the next Section. Through variables TPREC, THEAT, TCLOD, TRDSW, TRDLW, and TSRFC the user specifies the accumulation period (in hours) for accumulation arrays. Note that the accumulation periods operate independently of the posting times set in TSHDE. They define the frequency at which accumulated quantities are reset to zero:

TPREC = Precipitation

THEAT = Surface fluxes

TCLOD = Cloud water

TRDSW = Short wave radiation

TRDLW = Long wave radiation

TSRFC = Surface parameters

7.4 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, tills 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. Figure 8.2 shows a portion of the operational 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 grid type 99999 which 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. 8.2 grid type 94 is the 22km domain. 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.

```
    KGTYPE*******I5        ******* :(00094)********START OF THIS OUTPUT GRID******
    IMDLTY         *I5*          :(00083)
    DATSET         *A6*          :(EGDAWP)
    OUTYPE         *A6*          :(GRIBIT)
    NUFILE         *A6*          :(YES   )
      PROJ         *A6*          :(LOLA  )
      NORTH        *L1*          :(TTTTT)
      IMOUT        *I5*          :(00345)
      JMOUT        *I5*          :(00569)
      POLEI        *F11.6*       :(0.140845070)
      POLEJ        *F11.6*       :(0111.000000)
      ALATVT       *F11.6*       :(0000.000000)
      ALONVT       *F11.6*       :(0050.000000)
      XMESHL       *F11.6*       :(0.154069767)
      READLL       *A6*          :(NONE  )
      READCO       *A6*          :(NONE  )
 (PRESS ON ETA SFCS   ) Q=(   8), S=( 149), SCAL=( 3.0), SMTH=(00 00 00)
 L=(20000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000)
 (HEIGHT ON ETA SFCS  ) Q=(   1), S=( 149), SCAL=(-5.0), SMTH=(00 00 00)
 L=(20000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000)
 (TEMP ON ETA SFCS    ) Q=(  16), S=( 149), SCAL=(-4.0), SMTH=(00 00 00)
 L=(10000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000)
....
 (NGM 0.98230 SPC HUM ) Q=(  95), S=( 148), SCAL=( 3.0), SMTH=(00 00 00)
 L=(10000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000)
***DONE WITH THIS GRID***
    KGTYPE******I5*******:(00094)********START OF THIS OUTPUT GRID******
    IMDLTY         *I5*          :(00083)
    DATSET         *A6*          :(EGDAWP)
    OUTYPE         *A6*          :(GRIBIT)
    NUFILE         *A6*          :(YES   )
      PROJ         *A6*          :(LOLA  )
      NORTH        *L1*          :(TTTTT)
................
***DONE WITH THIS GRID***
```

Fig. 7.2. Portion of control file from the operational Eta post.

DATSET is the root around which the post creates output filenames. To this root the post appends the format of the output file and the forecast hour xx as specified in namelist FCSTDATA. Through the character string OUTYPE the user specifies the data packing to be used when writing the output file. Two formats are available: unpacked sequential binary and

GRIB 1. Setting OUTYPE to NO tells the post to write data using unformatted FORTRAIN writes. If DATSET equals NOHEAD when OUTYPE equals NOPACK, no headers are written to the binary output file. Otherwise, a grid header starts each file and each output field is preceded by a record denoting the type and level of the field. Setting OUTYPE to GRIBIT produces a GRIB 1 packed dataset.

When GRIB output is requested, the two digit forecast time is appended to DATSET to form the the first part of output filename. For example, the first output file generated by the Eta post using the control file in Fig. 8.2 would be named EGDAWPxx.tmyy, where xx is the forecast time and yy is the time used in the EDAS. For sequential binary output, .SbinFxx is appended to DATSET. 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/NO switch.

The indented variables in the header deal with the output grid and pre-computed interpolation weights. PROJ, NORTH, IMOUT, JMOUT, POLEI, POLEJ, ALATVT, ALONVT, and XMESHL are the basic set of parameters by which standard NCEP software defines different types of geographical grids. PROJ is a character*6 string denoting the type of output grid projection. Currently three projections are supported, namely POLA for polar stereographic, LOLA for latitude-longitude, and LMBC for Lambert conformal conic. If the user wants grid relative winds on the native model grid, PROJ must equal LOLA. NORTH is a logical flag for northern (. TRUE.) or southern (. FALSE.) 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 XMESHL define the north-south and west-east grid increment on transformed grid respectively. POLEJ and ALONVT are geodetic longitude and latitude of the center of the E-grid. ALATVT is only required for Lambert conformal grids. It is the latitude at which the projection is tangent to the surface of the earth.

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=l, imout) , j=l, jmout) using FORMAT 5 (gl2.6, lx). This option of the post has not been exhaustively tested since most users desire data on standard NCEP grids.

Whenever the user is not posting data on the model grid it is recommended that interpolation weights be pre-computed. The user tells the post to read an external weight file by setting READCO to YES. If READCO equals NO the post processor will compute all necessary interpolation weights prior to posting any fields. Source to pre-compute interpolation weights resides in ~wd22tb/etafcst/post/e2gd. See the Read me files in this directory for details. The user must ensure that the order in which interpolation weights are assigned in the template is the order in which the grids are listed in the control file (see Section 1.5 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 over 150 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 only those fields which are desired need to be listed in the control file. 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. The order in which pressure levels are specified in FCSTDATA maps directly to the left to right ordering of integers on the level line. For example, using the FCSTDATA shown in Fig. 8.1, moving left to right across the level line are pressure levels 50, 75, 100, 125, ... ,975, and 1000 mb. Fields may be posted to different pressure levels by editing namelist FCSTDATA.

As a further example consider the lines

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

from Fig. 8.2. 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 Bleck filter will be applied to data on the filled E grid and the output grid. Heights at all 39 isobaric levels as listed in Fig. 8.1 will be posted.

For data on constant eta layers two options are available. Setting the n-th integer on the level line to instruct the post to extract data on eta layer n. By "eta layer n" we mean the n-th eta layer using the top down vertical indexing of the eta model. At times it may be of interest to see what a selected field looks like in the n-th atmospheric (i.e., above ground) 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 settings could be

```
(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 (Flight level) fields and boundary layer fields. There are six FD levels. The ordering on the level line is from the lowest (914 m MSL) to the highest (3658 m MSL) 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. Two types of convective available potential energy (CAPE) and convective inhibition (CIN) are available. The first type (type one) starts the vertical integration from the lowest above ground model layer. The second type (type two) searches the six 30mb constant mass layers for the layer with the highest equivalent potential temperature. The CAPE and CIN calculation then starts from this level using this layer mean parcel. Type 1 CAPE and CIN are activated by setting the leftmost integer on the level line to 1. The second leftmost integer controls posting of type two CAPE and CIN. Both types may be requested. 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. 8.2 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.

7.5 The Template

The post processor was designed to run as a stand-alone executable. Figure 8.3 shows a script that can be used to run the Eta post processor on IBM. The file itag is used to specify the posting times for the Eta post processor. The file contains three 2-digit numbers xx. The first two-digit number indicates the first forecast time the user wishes to post; the second one is the interval between the posting times; and the third one specifies how many forecast times the user wishes to post. As shown in the template the post reads as input (1) namelist FCSTDATA, (2) the constants nfile (nhb), (3) a restart file, and (4) the control file.

```
#!/bin/ksh
#
#@ output = out.post
#@ error = err.post
#@ job_type = parallel
#@ class = dev
#@ total_tasks = 12
#@ node = 3
#@ wall_clock_limit = 00:45:00
#@ preferences = Feature == “dev”
#@ network.MPI = css0,shared,us
#@ queue
#
set -x
export MP_SHARED_MEMORY=yes
export MP_LABELIO=yes
export RESTRT=restrtxx
export tmmark=tm00
export INPUT=/emcsrc/wx20hc/input22_50

pwd
ls -x
#---------------------------------------------------------------------
ln -s -f fcstdata.parm       fort.11
ln -s -f nhb2250          fort.12
ln -s -f ${RESTRT}               fort.13
ln -s -f $INPUT/cntrl.parm          fort.14
ln -s -f wgts1                   fort.20
ln -s -f wgts2                   fort.21
ln -s -f wgts3                   fort.22
ln -s -f wgts4                   fort.23
ln -s -f wgts5                   fort.24
ln -s -f wgts6                   fort.25
ln -s -f omg                     fort.81
ln -s -f all                    fort.82
#
#---------------------------------------------------------------------
#   Run etapost.
#
poe /emcsrc/wx20hc/etapost/etapost.x_22km < itag > out.post
#
#----------------------------------------------------------------------
#---------------------------------------------------------------------
#   End of output job
#
date
echo “End of Output Job”
exit
```

Fig. 7.3. A script that can be used to run the Eta post processor on IBM.

7.6 Summary

We have described how to use the Eta post processor in conjunction with the model. The post processor was designed to run as a stand-alone executable. The user controls the post by editing a control file. In this file the user specifies which fields to post, smoothing options, data format, and output grids. When running the product generator to output the grids on the non-native model grid it is recommended to pre-compute interpolation weights.

While the post processor can generate numerous output fields, it will never post every possible field. Every user will eventually find need for some field not available from the post. When the inevitable happens, several options exist.

First, any user can edit copies of the model and post processor to generate the desired output fields. The arrays needed to calculate the field must be added to the restart file generated by the model. Subroutine CHKOUT writes the model restart file. Post processor routine INITPOST which reads this file must be correspondingly edited. The new field must also be added to the control file. Lastly, code to generate the desired field must be added to the post processor. Where this code is added is not particularly important. However, post processor subroutine MISCLN has traditionally served this "catch-all" purpose.

For those who do not wish to tinker with the post processor code an alternative solution is to compute the desired field(s) directly in the model. If this is deemed too expensive, the model could simply write the information required to generated the new field(s) to an output file. An external piece of code written by the user would compute the new field(.s) from information in this output file. If the user wanted to pack the new field(s) in GRIB 1, appropriately edited versions post processor subroutines GRIBIT (and their supporting routines) could be added to the user's post processor code.