A Guide to the Eta Model

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Update of

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Initial Setup

1) Extract the contents of the tar file with the following command:

    tar zxf worketa.tgz
    This will extract the contents of this file into a directory named worketa_all.

2) Go to the worketa_all directory and set up a few items that are machine dependent by running the setup script with either DEC, LINUX, or NORMAL as an argument for the script. NORMAL should cover all users not using DEC or **LINUX** machines.

EXAMPLE: If setting up the model on an **LINUX** workstation, then the command is **setup LINUX**.

3) Edit the file **make.inc** in **worketa_all/dprep/src/configure** to specify the compiler name (FC) and compiler flags (FFLAGS, often used to set the level of optimization). Appropriate examples for certain machines are contained in this directory.

4) Create the software libraries used when compiling other codes.

a) go to **worketa_all/libraries/bacio.source** (note: portions of pathnames before worketa_all will not be included in this manual, as they are unique to each user).

    * define the computer system being used in the file clib.h.

    For machines not included in the list, try the SGI and HP settings. The compilations in steps 5 and 10 link with the bacio library and are the real test of whether an appropriate version has been created.
    * Edit the file comp.com to uncomment (lines beginning with # are treated as comments by the script) one of the three options for compiling the C portion of the code. Special compiler flags are required to compile on HP and DEC machines. Once the file has been edited, enter **comp.com** to create the file bacio in worketa_all/libraries.

b) go to **worketa_all/libraries/** and enter the command **make_ip_w3** to create the w3lib, iplib, and bufrlib libraries.

c) go to the **dummyMPI** subdirectory.

    For HP workstations, enter make -f Makefile.hp; for IBM workstations, enter make -f Makefile.ibm; for **LINUX** machines use **make -f Makefile.linux**; others can simply enter make.

5) Change directories to **worketa_all/dprep/install** and enter the command: **build_dprep**

    This script builds the dprep (data preparation) executables.

If the compiler complains about unresolved references to items such as bacio_, try changing the system definition in the bacio library. Remake the bacio library, and then try reruning the build_dprep job.

6) Extract the topography data

If the topography data have been downloaded, they should now be placed into **worketa_all/eta/static/topo**. If not, the data can be retrieved from http://www.emc.ncep.noaa.gov/mmb/wrkstn_eta/topo.html
The data are grouped into tiles covering 30º of latitude by 60º of longitude.

The file names (e.g., U20N130W) give the coordinates of the southwest corner of the 10º X 10º region covered by the file.

7) Land/sea data information

The package defaults to use a 30" land/sea mask dataset. This dataset is broken up by latitude, with each tile covering 5º. The data needed for a given domain will automatically be copied into worketa_all/eta/bin/ and uncompressed by a script when initializing the model (described below). The naming convention is that the northernmost file is smask.30s.01 and the southernmost file is smask.30s.36.

The other two datasets (global_4m.ieee, global_8m.ieee) have 4 minute and 8 minute resolution, respectively, and are of poorer quality than the 30" data. If using the 4 or 8 minute data, uncompress the appropriate file in worketa_all/eta/bin and specify the proper SEARES value when editing the ETAIN file (step #1 of "Setting up and running the model") below.

8) Change directories to **worketa_all/eta/src/configure** and edit the **make.inc** file to set the compiler names and options. Examples from several workstation platforms are included in this directory. The -DLITTLE flag is critical for DEC and **LINUX** users, and the -DDEC flag is needed for DEC users.

9) Change directories to **worketa_all/eta/install** and edit the **set_parmeta** script. This script sets information later used to compile the model, and installs some resolution-dependent files.

   IM: Number of mass grid points along the first row, essentially half the total number of grid points in the west-east direction due to the horizontal staggering of mass and wind points (i.e., an IM=50, JM=99 grid is a square domain).

   JM: Number of rows in the north-south direction (NOTE: MUST BE ODD).

   LM: Number of vertical levels. For Eta vertical coordinate model runs it must be set to 38, 45, 50, or 60 to work with the included deta and radiation files. Sigma vertical coordinate runs require that LM be set to 25, 30, 38, or 45 to work with the included radiation files.

LSM: Controls the number of output levels for isobaric data (discussed below in "The post-processor" section). Should not require changing.

PT: The top pressure of the model atmosphere; 25 hPa is the value used at NCEP, and it must be set to 25 or 50 to work with the included radiation files.

HVAL: Character string used for symbolic links between files and FORTRAN unit numbers. Most machines need HVAL="fort.", but HP uses HVAL="ftn".

INPES, JNPES: These define how the model grid will be distributed over multiple processors (the model integrates on INPES x JNPES processors). Users running the model on a 1-CPU machine or a machine without MPI should set these equal to one.

10) Go to worketa_all/eta/install and enter the command: **buildall**

This script will set paths, use the information from the set_parmeta file to configure several items, and ultimately compile the model code, codes used to initialize the model, and codes that post-process model output.

11) You are now done with the initial set up.
Changing the model dimensions (IM, JM, LM) or the number of CPUs (INPES, JNPES) requires repetition of steps 9 and 10.

Getting the input data

1) Go to **worketa_all/dprep/bin** and decide on an input data set. The workstation Eta can be initialized from global GFS grib2 data, from the Eta model on grids 104, 212, 218 (always in tiled form), and 221 (usually in tiled form), or from NCEP global reanalysis data. There are appendices with details on: the WAFS form of the AVN ("WAFS input data"), tiled grid 221 ("tiled 221 input data"), tiled grid 218 ("tiled 218 input data") and global reanalysis data ("Reanalysis input data"). The areas covered by the Eta output grids and the operational 12 km Eta domain are shown in regions.gif. Scripts have been included to get the data via FTP and put it into the format needed to initialize the model. The scripts are used in the following way:

inputdata.scr input1 input2 input3 input4

input1 is the model cycle (00, 06, 12, or 18). It assumes the current day.

input2 is the final forecast hour of model data to get, effectively setting a limit on the length of the workstation Eta forecast.

input3 is the interval in hours between input model forecasts (sets the frequency at which the lateral boundary conditions can be updated; typically 3 or 6).

input4 is the form of data to get (gfs2, AVN, wafs, 104, 212, 221, tile, or tile218).

EXAMPLE: If the user wanted GFS grib2 data for a 24 hour model run based on the 00Z cycle with boundary condition updates every 6 h, the following command would be entered:

inputdata.scr 00 24 06 gfs2

2) Surface fields

Descriptions of the included time-independent fields located in **worketa_all/eta/bin**:

islope_1d_ieee, isltyp_1d_ieee, ivgtyp_1d_ieee :
These specify the slope, soil, and vegetation types.

alb1_ieee, alb2_ieee, alb3_ieee, alb4_ieee :
These are seasonal albedo files which are interpolated in time to get a starting value of albedo. This initial albedo value is refined by code that considers surface characteristics, such as snow cover and vegetation type.

maxsnoalb.bin :
A global file containing a maximum albedo for snow-covered surface. For example, a coniferous forest (with dark trees rising above the snow) will have a lower maximum snow albedo than snow-covered grassland.

veg.eta.grb :
This file contains vegetation fractions, stored as monthly values and interpolated in time to obtain the appropriate fractions for the day of the model run.

imsmask.ascii :
This file contains the land/sea mask used when processing the IMS snow data (a high-resolution NESDIS product that defines snow and ice cover, but not depth).

rfusaflw_ieee:
This file contains the land/sea mask used when processing the U.S. Air Force snow data (a lower-resolution product used to define the model snowdepth).

Setting up and running the model

1) Go to **worketa_all/eta/bin** and edit the namelist file **ETAIN** to set some details about the model run. NOTE: only edit the ETAIN file located in worketa_all/eta/bin; the ETAIN file in worketa_all/eta/runs is copied from this file.

   TLM0D,TPH0D: These are the center longitude (ºE positive, ºW negative) and latitude of the model domain.

   IM,JM,LM: The dimensions of the computational domain. These values were defined in set_parmeta in worketa_all/eta/install and should not be changed here.

PTINP: The model top pressure in Pa; the value was set in set_parmeta and should not be changed here.

DLMD,DPHD: The grid spacing in degrees in the east-west and north-south directions within the rotated lat-lon coordinate of the Eta model. An approximate relationship between horizontal grid spacing and DLMD & DPHD values is given below in the description of DT.

DT: The fundamental time step of the model (in seconds), which is a function of horizontal resolution. Some standard values used at NCEP are given below; they should provide computational stability for all flows. An overly long time step leads to model instability, typically apparent as a dramatic, non-physical oscillation in surface pressure. Note that the given values of DT divide evenly into 3600 so the proper number of physics/adjustment steps will be performed each hour.

DLMD,DPHD	appx. hor. res. (km)	DT(s)
.067,.066	10	20
.099,.097	15	30
.154,.141	22	60
.222,.205	32	90
.333,.308	48	120
.577,.538	80	200

IDTAD: The frequency of advection time steps (should remain 2, which means that advection is called every other fundamental time step).

IMONTH,IDATE,IYEAR,ISTRTIM: Together these specify the initial time of the run.
ISTRTIM is the hour of the starting time (e.g., a run based on 12Z data has ISTRTIM=12)

NSOIL: The number of soil levels (should remain 4).

NINIT: The number of input data files.

TBOCO: Interval in hours between successive input forecast files (typically 3 or 6).

INIT_IN(#):
The names of the input data files. The naming convention is YYMMDDCCHHH.ETAmod,
where YYMMDD is the year, month and day, CC is the cycle time, HHH is the hour of the forecast, and mod is the extension given to the particular input dataset (104, 212, 221, wrk, _avn, _tile, _wafs, _rnl). It is possible to set up an automated system to automatically specify these file names if running in real-time (see Appendix: Automating the process). This list should contain NINIT file names.

INIT_OUT: The directory where the initial and boundary condition files will be written (should not require modification).

TOPO_IN: Location where the raw (10º x 10º) topo files are stored.

TOPO_OUT: Output file of topography data on the current model domain.

SEARES: The resolution of the land/sea mask data to use (30, 4, or 8). Refer to step #7 in "Initial setup".

FRACLK: A parameter set between 0 and 1 to help limit/encourage the inclusion of small bodies of water in the land/sea mask. Smaller values will tend to reduce inclusion of smaller lakes and ponds. Most critical when using the 30" data, which has incredible levels of detail.

GRIBSOIL:
If .TRUE. then soil temperature and moisture are initialized from the input GRIB dataset.
If .FALSE. then soil fields are initialized from the sfcanl file.
This must be set to .FALSE. if initializing from the WAFS form of the AVN! Described more in the appendix "WAFS input data".

SIGMA: This logical switch defines the vertical coordinate to be used. When SIGMA is set to .false. the Eta coordinate is used; when SIGMA is .true. the sigma coordinate is used.

REAN: A logical switch. If .TRUE. , then surface characteristics will be read from the REAN_SFC file. Should remain .FALSE. unless initializing from NCEP global reanalysis files.

REAN_SFC: Path of the reanalysis file to be used to initialize surface and soil characteristics. Only relevant when using NCEP global reanalysis data and REAN=.TRUE.

2) enter the command: **new_prep.sh**

This script runs programs that generate a topography file and the initial and lateral boundary conditions. The topography needs to be generated only once per domain, so the line of the script running etatopo.exe can be commented out if multiple runs are made on the same domain. This script generates two files of standard output, topo.out and initbc.out.

A new function of this script is to create a station list used when generating hourly BUFR output (described more fully in Appendix: BUFR output). The included list of possible stations only contains stations located within the U.S. operational Eta domain.

One can add their own stations by following the format within the file eta_staids.parm in the worketa_all/staids directory. Here is a sample line:

724060 39.18N 76.67W KBWI 10 BALTIMORE/WASH_INTL MD 47 == TAF 2-99

724060 is the WMO Index number with a zero at the end
39.18N is the latitude (always a positive number, followed by N or S)
76.67W is the longitude (always a positive number, followed by E or W)
KBWI is the ICAO identifier
10 helps control which grid point gets selected. Only the first digit is relevant. A "0" takes the nearest gridpoint regardless of whether it is land or sea, a "1" forces the nearest land point to be selected, and a "2" forces selection of the nearest water point.
BALTIMORE/WASH_INTL MD is a description of the location.
47 is the station elevation in meters, which is only a description.
== TAF 2-99 is another description that is not used by the code.

NOTE: Make sure the added rows have columns which line up with the current entries in the file; this formatting is important.

3) enter the command: **cd ../runs**

4) edit the **fcstdata.meso** file, which controls details of the model run.

```
&FCSTDATA
TSTART=00.0,TEND=24.00,TCP=99.0,RESTRT=.FALSE.,SINGLRST=.TRUE.,
SUBPOST=.FALSE.,
NMAP=5,TSHDE=00.0,06.0,12.0,18.0,24.0,99.0,99.0,99.0,99.0,99.0,
        99.0,99.0,99.0,99.0,99.0,99.0,99.0,99.0,99.0,99.0,
        99.0,99.0,99.0,99.0,99.0,99.0,99.0,99.0,99.0,99.0,
        99.0,99.0,99.0,99.0,99.0,99.0,99.0,99.0,99.0,99.0,
        99.0,99.0,99.0,99.0,99.0,99.0,99.0,99.0,99.0,
SPL=10000.,15000.,20000.,25000.,30000.,35000.,40000.,45000. ,50000.,
    55000.,60000.,65000.,70000.,75000.,80000.,85000.,90000. ,92500.,
    95000.,100000.
NPHS=8,NCNVC=8,NRADSH=1,NRADLH=2,NTDDMP=1,
TPREC=6.0,THEAT=6.0,TCLOD=6.0,
TRDSW=6.0,TRDLW=6.0,TSRFC=6.0
NEST=.FALSE.,HYDRO=.TRUE.,SPLINE=.TRUE.
&END
```

TSTART: Sets the beginning forecast hour (=0.0 unless restarting a forecast as discussed in Appendix: Restarting a forecast).
TEND: Sets the ending forecast hour.
RESTRT: Logical switch that tells the model whether it is starting from an initial condition file (if =.FALSE.) or from a model restrt file (if =.TRUE.). Typically set to .FALSE.; an example of when it might be true is given in the appendix ("Restarting a forecast").
SINGLRST: Should always be .TRUE. for what is described in this manual.
NMAP: Specifies the number of times at which the model will generate output.
TSHDE: List of the forecast hours for which the model will generate output. The model considers the first NMAP values in the list. NOTE: Must

generate output at every forecast hour if planning on generating BUFR output (forecasts at specific points, see "Appendix: BUFR output" for more details).

SPL: These are the pressure levels (in Pa) at which isobaric output can be generated by the post-processor. The number of levels defined should be the LSM value defined in set_parmeta in step #9 of the "Initial setup" section.

NPHS: The physics package is called every NPHS time steps. The surface physics are usually run about every 10 minutes of forecast time (NPHS set to an even integer such that NPHS x DT 600). For example, a 15 km resolution run using a 30 s time step should use NPHS = 20. Runs with high resolution in the horizontal and vertical may wish to run with NPHS set such that the physics are called about every 300 s.

NCNVC: The frequency of calls to the convective parameterization. Should be the same value as NPHS.

NRADSH,NRADLH: The interval in hours between calls to the radiation schemes (shortwave and longwave). These values are typically 1 and 2, respectively.

NTDDMP: The frequency at which the divergence damping is applied (typically 1, i.e., at every time step).

The next six values specify the number of hours over which the following types of parameters accumulate prior to being reset to zero. They should be set considering the frequency at which output is generated (i.e., resetting precipitation totals every 2 h will be problematic if output is generated every 3 h).

TPREC: precipitation
THEAT: average latent heating associated with precipitation
TCLOD: average cloud fractions
TRDSW: short wave radiation
TRDLW: long wave radiation
TSRFC: surface fluxes (e.g., average sensible heat flux)

NEST: should remain .FALSE. for workstation Eta purposes.

HYDRO: .TRUE. uses the default hydrostatic dynamics, while .FALSE. invokes Janjic's nonhydrostatic extensions to the Eta model. Note: Running in nonhydrostatic mode adds significantly to the run time (in some cases around a 50% increase), and will have a larger forecast impact at resolutions finer than 10 km.

SPLINE: Only relevant when running with the sigma coordinate. If .TRUE. a spline fit is used when producing output. This technique produces much smoother underground fields (such as reduced sea-level pressure), but has little impact at above-ground output levels. Recommendation is to set the switch to .TRUE.

5) Running the model:

enter the command: **run.com_mpi** possibly with the following option:

kf - will run the model using Kain-Fritsch (KF) convection rather than Betts-Miller-Janjic (BMJ) convection. Due to the significantly different

approaches taken by these convection schemes, large differences in precipitation and low-level temperatures are possible when switching from one to the other.

If no option is given after the command, BMJ convection will be used.

As the model runs, it will generate restrt files [with names such as restrt000.quilt.t00s if running the model on a 1-CPU computer, or restrt000.t00s if the model is run on more than (INPES x JNPES) CPUs] at each specified output time. These restrt files contain the model forecast, but must be post-processed to be useful.

The post-processor

1) Run the post-processor with the following command:

outjob_special stime etime tint type

where stime is the starting time (typically 00), etime is the final forecast hour, tint is the time interval between forecast output files, and type is an argument set to **latlon** or **lmbc** to interpolate to a latitude-longitude or Lambert Conformal output grid, respectively.

This script will perform a number of functions: "quilt" the restrt files (primarily calculate a reduced sea-level pressure, which is not done in the integration of the model) if needed, run the post-processor to create GRIB output on the model's native grid, and interpolate the GRIB output onto a standard projection (if the fourth argument type is set to either latlon or lmbc).

As described more fully in the appendix (BUFR output), the job outjob_special_bufr should be run in place of outjob_special if generating hourly BUFR output.

The remaining discussion in this section is fairly detailed, and not critical for the first-time user. It describes how to control which data gets output by the post (i.e., fields, levels) and how to specify a specific output grid. Controlling the post

The cntrl.parm file (unit 14) controls the fields and levels that are written to the output GRIB file. Each parameter is controlled by two lines in this file. (TEMP ON PRESS SFCS) Q=(16), S=(8), SCAL=(-3.0), SMTH=(00 00 00) L=(00000 00000 00000 00000 00000 11111 11111 11110 00000 00000 00000 00000)

The first line describes the field, sets the Q and S values (no longer used), and defines the precision and smoothing.

SCAL defines the precision that is written out to the GRIB data. Positive values denote decimal scaling (maintain that number of significant digits), while negative values denote binary scaling (precise to ; SCAL=-3.0 gives output precise to the nearest). Higher resolution runs should output the data

with more precision if performing complex diagnostics on the data that use higher order derivatives (e.g., Q vectors, vorticity advection).

The final item on the first line is the smoothing block SMTH. The first value sets the number of smoothing passes applied to the staggered (where mass and wind points are separate) grid and the second value sets the number of smoothing passes applied to the filled grid (the post "fills" the native grid so there are mass and wind data at all grid points). The third value activates a 25-point Bleck filter on the output grid, which for the workstation post is the filled grid. The Bleck filter removes small scale features and largely preserves extrema in the data even after multiple applications. As seen in the cntrl.parm file, smoothing typically is not performed on most fields.

The second line controls the output levels (and whether a field will be created at all) by providing on/off switches for the output.

For multi-level data the switches (1 = output, 0 = do not output) control which levels to create output for, with the lowest pressure level (furthest from ground) controlled by the leftmost element of the string. This ordering can be reversed by using 2's in place of 1's; 2's control output from the ground up. For isobaric data the levels being switched on and off correspond to the SPL values in the fcstdata.meso file, and the first LSM values in the string are used. For single level data, the leftmost number is used as the switch (1 = output, 0 = do not output).

Examples (assuming LSM=39, with SPL values defined every 25 hPa from 50 hPa to 1000 hPa):

(MESINGER MEAN SLP) Q=(8), S=(138), SCAL=(-0.1), SMTH=(00 00 00) L=(10000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000)

(TEMP ON PRESS SFCS) Q=(16), S=(8), SCAL=(-3.0), SMTH=(00 00 00) L=(00000 00000 00000 00000 00000 11111 11111 11110 00000 00000 00000 00000)

(TEMP ON PRESS SFCS) Q=(16), S=(8), SCAL=(-3.0), SMTH=(00 00 00) L=(22222 22222 22220 00000 00000 00000 00000 00000 00000 00000 00000 00000)

Translations: The first output field is a mean sea level pressure reduction designed for use with the Eta model. SCAL=-0.1 specifies that the value is stored to a precision of , or pretty close to the nearest Pa.

The second example is isobaric temperature. The initial 25 0's suppress the output of this field between 50 hPa and 650 hPa, while the subsequent 14 1's generate output between 675 hPa and 1000 hPa. SCAL=-3.0 writes out the data to the nearest 0.125.

The third output field is identical to the second, but by using 2's instead of 1's it is clearer that output is being generated for the 14 output pressure levels closest to the ground.

Adding a field

More fields are included in the file cntrl.example; the easiest way to add a field is to copy one of these into the cntrl.parm file. The file AVBLFLDS in worketa_all/post_new lists all fields available for posting, but in a different format.

Suppose highest freezing level data is desired. Searching through the AVBLFLDS file finds the proper two lines.
    DATA IFILV(165),AVBL(165),IQ(165),IS(165) &
/1,'HIGHEST FREEZE LVL ',007,204/
The crucial piece of information from above is actually the character string in quotes on the second line. The numbers listed after the character string give the GRIB specification of the field. The first value is the GRIB parameter number (007 = geopotential height) and the second is vertical coordinate (204 = highest tropospheric freezing level; a special NCEP definition). The number preceding the character string is a switch that indicates whether the variables are stored on mass (1) or wind (0) grid points.

To add this field into the cntrl.parm file, this character string (including any spaces) is placed between parenthesis on the first line of the cntrl file. Proper formatting is crucial in the cntrl.parm file; make sure any lines added match the format of the other lines in the file. Q and S can be set to any value as they will be replaced by the GRIB definitions described above as the program runs. Scaling and smoothing are set to their desired values, and since this is single level data, only the leftmost element of the second line is set to 1. The lines added to the cntrl.parm file would look something like this:

(HIGHEST FREEZE LVL) Q=(7), S=(204), SCAL=(-2.0), SMTH=(00 00 00)
L=(10000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000
00000)

Interpolation to other grid projections

The workstation post creates GRIB output on the native e-grid (files with names like EGRD3Dhhh.t00s), but this output on the rotated latitude-longitude projection of the Eta model is not readily degribbed by most software packages. The outjob_special script uses the included GRIB utility copygb to interpolate the native grid data onto regular lat-lon (latlon_hhh) and Lambert Conic Conformal grids (lmbc_hhh), where hhh represents the forecast hour. These interpolated GRIB files on standard map projections should be much easier to degrib.

One item to point out about copygb is that the binary precision specified in the cntrl.parm file will not automatically carry over to the copygb output files. The copygb lines within the outjob_special script specify a scaling though the "-s" flag, but this scaling is applied equally to all fields. This indiscriminate scaling might make the lmbc and latlon files unnecessarily large. A way to maintain control over the precision of various fields is to use more decimal

scaling (SCAL > 0) in the cntrl.parm file. Decimal scaling from the original EGRD3D file will automatically carry over to the interpolated GRIB fields without using a "-s" option. A possible solution is given in the cntrl.dec file which avoids using binary scaling. To use decimal scaling exclusively the following changes would need to be made to the outjob_special file: 1) change the symbolic link from cntrl.parm to cntrl.dec; 2) remove the -s"2,-3" from the copygb.x lines. This purely decimal scaling option was not thoroughly tested, so it may require some tuning by the user.

The post generates the files outjob_input_lat and outjob_input_lmbc that define the destination grids for copygb. The values in these files are appropriate for the domain and resolution of the model, but they could be modified by the user if desired. (NOTE: The post will overwrite these files each time it runs, so save to another file name if making modifications)

The file outjob_input_lat contains a string of numbers beginning with 255 that describes the lat-lon output domain. These numbers have the format:

255 0 IDIM JDIM LAT1 LON1 128 LAT2 LON2 DLAT DLON 64

where

IDIM, JDIM: The dimensions of the output regular lat-lon grid.

LAT1, LON1: The latitude and longitude of the southwest corner of the output grid expressed in millidegrees. For example, a corner point at 15ºN, 112.5ºW would be expressed as 15000 -112500.

LAT2, LON2: As with LAT1, LON1, but for the northeast corner of the output grid.

DLAT, DLON: These are the spacings between output grid points in millidegrees of latitude and longitude.

The file outjob_input_lmbc has a slightly different string of numbers:

255 3 IDIM JDIM LAT1 LON1 8 CLON DX DY 0 64 TLAT1 TLAT2

where

IDIM, JDIM: These are the dimensions of the Lambert Conformal grid.

LAT1, LON1: The southwest corner specified as in the lat-lon output grid.

CLON: The center longitude of the lambert conformal projection. It will default to be the same as TLM0D (the center longitude of the model).

DX,DY: These are the grid spacings at the true latitude in the X and Y directions. Values are expressed in meters, and default to the approximate spacing of the filled native e-grid (with both mass and wind data at all points).

TLAT1, TLAT2: These are the "true latitudes" of the lambert conformal projection. By default they both are equal to the center latitude of the model.

These values should provide sufficient information to "degrib" the data regardless of the software package being used.

Aside for GEMPAK users:

A simple degribbing script for GEMPAK is included in the package. Running outjob_special with five arguments instead of four will automatically degrib either the lmbc or latlon data into a GEMPAK datafile in the directory worketa_all/gem_out. The fourth argument is either lmbc or latlon, and the fifth argument is the name of the GEMPAK datafile.

EXAMPLE: To post-process 12 h of model data at a 3 h interval, interpolate to a Lambert Conformal grid, and finally degrib into the GEMPAK file lmbc_test.grd, the following command would be used:

    outjob_special 00 12 03 lmbc lmbc_test.grd

Additional features

Time dependent data

For downloading of time dependent data go to directory **worketa_all/data** and run script **get_data.sh**. Script will download global GFS forecast data set on standard pressure levels in grib2 format up to 48h of forecast with 6h interval and for actual date.

If you want to download GFS forecast up to 72 or more hours open script and edit line

for ftime in 00 06 12 18 24 30 36 42 48;do

appending more forecast hours.

Script will also download actual data for surface time dependent variables, snow and sea surface temperature. Some of surface data will be removed from NCEP servers during September and December 2008, please track changes on page
http://www.nco.ncep.noaa.gov/pmb/docs/GRIB1_to_GRIB2.shtml.

Reanalysis input data

This version incorporates code that allows Eta model runs to be made starting from NCEP global reanalysis data. Two types of reanalysis files are utilized: Isobaric analyses (filenames of type pgb.f00yymmddhh, where yymmddhh is an eight-digit number specifying year, month, date, and hour), and surface

fields on a gaussian grid (filenames of type grb2dyymmddhh, with yymmddhh having the same meaning as above). "pgb" files must span the entire length of the desired Eta model forecast, while a "grb2d" file is needed only for the initial model time. These files should be placed in the worketa_all/data/grib/ directory for processing.

The script etagrib_reanalysis.sh script processes the "pgb" files. It requires three line arguments. Example:

   etagrib_reanalysis.sh stime etime int,

   stime is the starting date and time (yymmddhh),

   etime is the ending date and time (yymmddhh),

   int is the interval in hours between reanalysis files (hh, should be 06)

In the ETAIN file in the worketa_all/eta/bin/ directory, be sure to set REAN=.TRUE., and specify your "grb2d" file in the definition of REAN_SFC.

Forecasts generated from global reanalysis data may be of lower quality than those initialized from other data sources. The data are coarser than the real-time sources, particularly for surface characteristics such as snow cover, and soil temperature and moisture.

Nesting

Nesting within the Eta model is one way (the higher-resolution nest does not influence the lower resolution "parent" domain). Nesting within a domain, rather than simply running a higher resolution domain from downloaded input grids, offers potential advantages in the resolution and time frequency of lateral boundary conditions. The process outlined below differs from the nesting done at NCEP, but allows for easier implementation (no additional codes needed) within the workstation Eta.

The parent domain is run first, and output should be generated every hour if possible. It is also important to generate isobaric output every 25 hPa from 50 hPa down to 1000 hPa, as well as soil temperature and moisture at all four soil levels. This initial run should be postprocessed, with Lambert Conformal (lmbc) output generated, as the lmbc grid closely matches the grid of the model domain. Go to the worketa_all/dprep/bin/ directory and run the inputdata.scr job with "lmbc" as the grid type. For example, inputdata.scr 00 24 01 lmbc, would process 24 h worth of the parent run at a 1 h interval. This will process the output from you parent run in the same way it would process an operational Eta or AVN run. The output files in worketa_all/data/prep/ will have filenames ending in "ETAwrk"

One must then return to worketa_all/eta/bin/ and edit the ETAIN file to define the higher-resolution nest run to be initialized with the "ETAwrk" files. At this point it becomes another normal model run, which is initialized with the new_prep.sh job and run with the run.com_mpi script as described in the main body of this manual.

Long-range forecasts (beyond 256 hours)

The post-processor code will have problems processing forecasts beyond 256 h. A slight code modification enables longer forecasts. In the post code worketa_all/post_new/, the routine GRIBIT.f needs a one-line change. The definition of ID(17) on about line 181. When ID(17)=1, the output time unit is one hour. Setting ID(17)=10 changes the output time unit to three hours, allowing proper processing out to 3 x 256 = 768 hours. Setting ID(17)=11 changes the output time unit to six hours, allowing processing out to 1536 hours, but going beyond 999 hours will cause other problems.

BUFR output

In addition to the more familiar GRIB-based output, where output is interpolated onto a grid covering a region, BUFR-formatted output can also be generated. These BUFR-formatted output data are not interpolated onto a grid; they represent information directly from a model gridpoint at an hourly interval. Thus it provides highly detailed information for a specific location.

IMPORTANT: Generating BUFR output requires output of restrt files at each forecast hour.

The new_prep.sh script generates a binary file containing information about the stations in the model domain. After the model has run, the special post-processing job outjob_special_bufr is run. It generates GRIB output like the standard outjob_special job, then runs two additional programs to create the class1.bufr.t00s file. The class1.bufr.t00s file contains the hourly station data in BUFR format.

Automating the process

When the workstation Eta is run in real-time over the same domain, the editing process on the ETAIN file becomes tedious. After all, the only items being changed are date specifications. A crude sample of how the process can be automated is included with the files ETAIN_raw and new_prep.sh_auto in the worketa_all/eta/bin directory. The script new_prep.sh_auto uses the sed command to substitute the current date for variables in the ETAIN_raw file, and output an ETAIN file. To facilitate running new_prep.sh_auto as a crontab job it was required to change directories to an explicit path (equivalent to worketa_all/eta/bin) so the relative paths in the rest of the script would make sense. Similar directory specifications are needed for the "data_prep" job in worketa_all/dprep/bin and with run.com_mpi in worketa_all /eta/runs.

The digital filter

The Eta model has a filter that can be applied at the beginning of the forecast to give smoother fields over the first few hours of the forecast. To use it, the call to DIGFILT in worketa_all/eta/src/etafcst_all/EBU.F needs to be uncommented. Then in worketa_all/eta/src/etafcst_all/DIGFILT.F the parameter NTIM needs to be set. NTIM is the number of time steps that the

model will integrate forward and backward from the 0 h forecast time while filtering. Larger values of NTIM cut off lower-frequency phenomena and cause more smoothing. Overly large values of NTIM cause the model to fail. A good starting point for NTIM is a value that will give NTIM x DT 2400 s. Filtering is most useful when going from a coarse initial analysis to a very high resolution Eta model run. Filtered and unfiltered forecasts converge fairly quickly; filtered runs may give more aesthetically pleasing results during the initial 3-6 h of the forecast.

Restarting a forecast

This option would primarily be useful if for some reason the model could not be run over a single block of time. Maybe there is a conflict with other users on a shared computer resource. In any case, one recent addition to the model's capabilities (courtesy of T. Black) is a "true" restart capability. For example, an intended 24 h forecast has only integrated 12 h when the model run must be halted. Rather than starting again from scratch, the run can be restarted at the 12 h forecast point and integrated to completion. The code has the intelligence to skip the necessary records in the lateral boundary condition file. (NOTE: This new capability will create problems if the user tries to restart the model as has been done in the past with multiple lateral boundary condition files).

To use this option, the TSTART value in the fcstdata.meso file should be changed to the hour where the model will be restarted, and RESTRT should be set to .TRUE. The values of TSHDE should reflect the output desired from the restarted run. Run outjob_special on the initial portion of the run; this step is important to "quilt" the file to be restarted from, assuming the run is being made on a single processor. The run.com_mpi file needs to be modified in two ways: the removal of restrt* files near the top should be removed or commented out, and the link to init.file should be changed to a link to the appropriate restrt file.

WAFS input data

The WAFS form of AVN has global data divided into 8 90º x 90º octants:

    a) The region covered by each octant is shown in the GIF image wafs_octs.gif in worketa_all/dprep/bin.

    b) The user of this dataset may wish to edit the list of octant numbers to process found near the end of process_grib.scr. This list must end with the number -9.

    c) WAFS files are small for two main reasons: they contain 11 isobaric levels (the full AVN grids have 26), and the data is "thinned" near the poles to counter the convergence of meridians. The resolution is 1.25º x 1.25º near the equator.

    d) sfcanl is the surface analysis from an AVN model run; it must be used for soil field information when using WAFS data, as the WAFS grids themselves do not have soil information. The script that processes WAFS data automatically downloads the appropriate sfcanl file. The logical switch

GRIBSOIL in the file ETAIN specifies whether GRIB-based or sfcanl-based soil fields will be used. The sfcanl file is a "big-endian" binary file, so LINUX/DEC users will have to modify the program READSFC.f in worketa_all/eta/src/prep/initbc where the sfcanl file is opened and read. A sample open statement is provided in the code.

Tiled 221 input data

Special comments about the grid 221 data, which is obtained in "tiled" form:

a) The region covered by each of the 36 tiles is displayed on the webpage http:// www.emc.ncep.noaa.gov/research/tiles.221.html. Some tiles along the boundary of this region are not completely filled with data, as this output grid extends beyond the computational domain of the operational Eta along part of the boundary.

b) The user of this dataset will have to edit the "tilelist" string in the get_data.scr file to obtain the tiles needed for a particular domain. The code which merges these tiles is fairly general, so any normal square/rectangular region should work.

c) The tiled grid 221 dataset provides 32 km horizontal resolution data, and due to the tiling a limited volume of data will cover a typical workstation domain. The region covered includes essentially the entire computational domain of the operational Eta, opening up a vast region to workstation Eta runs.

Tiled 218 input data

Special comments about the grid 218 data, which is obtained in "tiled" form:

Most comments above describing the tiled 221 files apply here, with important differences being that the resolution is 12 km, there are 54 tiles, the region covered is a limited subset of the Eta domain, and a map of what is covered by each tile is available in worketa_all/dprep/bin/218_tiles.gif

The Eta: brief history, summary, results, discussion

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The Eta model is a descendent of the original code that I wrote in early 1973. The approach followed was to use to the extent possible the schemes and ideas of Akio Arakawa, in a limited area model on the E grid, but with an improved grid coupling scheme (Mesinger 1973). That very first code already had features that remained in the "standard" Eta model and also in that of the

Eta "sibling" NCEP's NMM (Nonhydrostatic Mesoscale Model) code until the present time: the Lorenz-Arakawa first and second moment conserving vertical advection scheme (e.g., Arakawa and Lamb 1977), and a lateral boundary conditions (LBC) scheme (Mesinger 1977). This LBC scheme has variables defined along a single outer line of grid points, with one less condition specified at the outflow than at the inflow points – as required by the mathematical nature of the equations being solved (e.g., Charney 1962). At the outflow points tangential velocity components are extrapolated from inside of the model domain; thus, there is no "boundary relaxation" that became almost universally used a few years later and remains so at present.

Having learned at a meeting in May 1973 of the scheme I called "forward-backward", that seemed ideal for the application of the 1973 grid coupling method (Mesinger 1974), this very first code was rewritten now with the participation of Janjic, so as to use the grid coupling within the forward-backward scheme. The grid coupling scheme suppresses separation of solutions on two C-subgrids of the model's E-grid. Janjic has extended the 1974 grid coupling scheme to the 3D case (Janjic 1979). The scheme is used in a split mode, with short "adjustment" gravity-inertia time steps, yet for stability twice as long as the leapfrog scheme would permit; and steps for advection twice as long as the adjustment steps. Janjic has also added a "minimum" dry physics. The first short report in English on the use of the resulting 3D code emphasized the successful performance of the grid coupling in combination with the lateral boundary condition scheme in controlling the lateral boundary noise (Mesinger and Janjic 1974).

Over the years numerous improvements and code rewritings followed. The major ones in terms of being either unique or pioneering in its implementation in the Eta, and in remaining in the code until present, might be listed as follows – roughly in the chronological order.

• Arakawa-type momentum advection scheme for the E/B grid of Janjic (1984). The scheme conserves enstrophy and energy, as defined on the C-grid, in horizontal advection within the nondivergent barotropic part of the flow. As a result it maintains average wavenumber within the horizontal nondivergent flow, thereby enforcing a strong constraint on the false systematic cascade of energy toward smaller scales. Thus, it very effectively suppresses the spurious generation of noise in the advection process;

• The eta vertical coordinate (Mesinger 1984) that achieves approximately horizontal coordinate surfaces, and thus prevents pressure gradient and other errors due to steep topography that can occur with terrain-following systems. The approach of Simmons and Burridge (1981) was generalized in Mesinger (1984) to the eta to conserve energy in transformations between the potential and the kinetic energy in space differencing; and generalized further to the 3D case by D. Zupanski, then Gavrilov (Mesinger et al. 1988). The material of Mesinger (1984) is included in a review paper by Mesinger and Janjic (1985).

• Numerous features of the comprehensive physics package, put together originally by Janjic (1990, 1994). The package includes
  - a modified Betts-Miller convection with the scheme choosing its reference moisture profiles depending on a nondimensional "cloud

efficiency" (Janjic 1994; see also a convection scheme essay written for participants who want to do lab problems using the scheme);

   - an explicit parameterization of the molecular sublayer over water surfaces with three regimes according to Liu et al. (1979), Janjic (1994);

   - Mellor-Yamada 2.5 turbulence scheme with a unique treatment of its realizability problem (Mesinger 1993; Janjic 2002);

   - wind direction dependent form drag scheme (Mesinger et al. 1996);

   - Zhao (Zhao and Carr 1997; Zhao et al. 1997) or, in later versions, Ferrier (Ferrier et al. 2002) cloud physics scheme. The code using the Zhao scheme can be found on the DVD that accompanied the March 2006 issue of the Bulletin of the American Meteorological Society, since this code was used for the North American Regional Reanalysis (NARR, Mesinger et al. 2006). The Zhao scheme version of the Eta, being more efficient, may also be a good choice for seasonal forecasting and regional climate applications of the model;

   - Noah land-surface scheme (Chen et al. 1996; Ek et al. 2003).

• An option to run the model as nonhydrostatic, using the scheme of Janjic (Janjic et al. 2001). The scheme approximates the vertical acceleration by time-differencing the hydrostatically computed vertical velocity, thus avoiding an extra prognostic equation for the vertical velocity as needed in conventional nonhydrostatic models.

While the "Betts-Miller-Janjic" (BMJ) scheme can be considered a "standard" Eta convection scheme, an option to use the Kain-Fritsch scheme (Kain and Fritsch 1993; Kain 2004) is available and tends to be a popular Eta lab problem.

The Eta model officially became the operational NCEP regional forecasting model in 1993, having demonstrated skill considerably superior to that of the previous U.S. NMC (National Meteorological Center) regional operational models LFM (Limited-area Fine Mesh) and the NGM (Nested Grid Model). This increased skill was demonstrated to derive to a significant degree from the use of the eta coordinate (e.g., Mesinger and Black 1992). A two-year parallel in the mid- to late nineties showed a substantial superiority of the Eta also over the so-called Regional Spectral Model (RSM), e.g., Mesinger (2000).

An Eta downstream windstorm result much worse than that of the sigma system MM5 model, and a subsequent paper by Gallus and Klemp (2000) led however to a rather widespread belief that the eta coordinate is "ill suited for high resolution prediction models". Statements that the Eta was doing worse than the MM5 in placing precipitation over the U.S. mountainous Pacific northwest were also published (Colle et al. 1999). This led NCEP's Environmental Modeling Center (EMC) to decide on the sigma coordinate when developing in the early two-thousands its version of the so-called Weather Research and Forecasting (WRF) model, the NMM. The NMM was developed from the Eta so that it shares most features with the Eta, which is the basis of its having been referred to above as the Eta "sibling" model. It should be pointed out though that the main motivation for the development of the WRF model was the coding structure, meant to enable running the model with user choices of routines and in fact as it eventually turned out also of the dynamical core itself. The belief of the present author however is that progress in NWP skill comes not so much by using various routines as

user choices, but more by understanding and improving individual routines and schemes, an approach that the WRF project was not designed to encourage.

The development of the Eta was nevertheless continued, partly with the support of NCEP's EMC. Specifically, a refinement of the eta discretization was developed (Mesinger and Jovic 2004) so as to address the "Gallus-Klemp" problem the original step-topography discretization had of separation of flow in the lee of a bell-shaped ("Witch of Agnesi") mountain. The solution arrived at can be considered a simplification of the "shaved cells" method of Adcroft et al. (1997). Using the refinement (the "slopes" option) vertical steps are replaced by topography descending, if decided appropriate, one layer thickness in between four neighboring height points. This and several other code improvements are present in the Eta code that was used in the preceding 2005 ICTP Regional Weather Predictability and Modelling workshop, posted at the CPTEC's (Center for the Weather Prediction and Climate Studies, Cachoeira Paulista, SP, Brazil) Eta web site, http://www.cptec.inpe.br/etaweb/. The site contains a list of developments compared to the standard NCEP Eta code.

As to the second alleged eta coordinate problem of the placement of precipitation less accurate than that using the sigma coordinate, overwhelming evidence has accumulated since this suggestion was made strongly supporting precisely the opposite. As to the most recent and very comprehensive results in that sense, precipitation plots in DiMego (2006) and Mesinger (2008) can be referred to, in particular the latter as it shows the precipitation placement skill of the Eta vs that of the sigma system models NMM and NCEP GFS (Global Forecasting System) separately for the U.S. mountainous western "hi res window" ("West") and the much flatter eastern one ("East"). Accordingly, in contrast to NCEP, several major modeling groups have recently moved from sigma towards eta or eta-like coordinates, including the European Consortium led by the German Weather Service (Deutscher Wetterdienst, DWD), Steppeler et al. (2006), and Goddard Institute for Space Studies (GISS), Russell (2007), with the authors cited reporting on significant improvements compared to sigma; note in particular the title of the latter.

Subsequent to the ICTP 2005 workshop a problem was noticed of unrealistically low temperatures occasionally occurring in some Eta basins and was identified as due to a problem of the Lorenz-Arakawa vertical advection that was used for slantwise advection along basin slopes. Since the scheme includes information on how much mass is being exchanged the slantwise advection was replaced by a conserving Lagrangian scheme, which removed the problem. This improved code is also posted on the CPTEC Eta site.

The original NCEP Eta OI data assimilation scheme was eventually replaced by an Eta 3D-Var scheme (EDAS), that over the years was made more and more and finally completely self-cycling and independent of the NCEP Global Data Assimilation System (GDAS), Rogers et al. (1995, 1996, 2001). However, it was inadvertently noted in the early two-thousands that a simple space interpolation off the GDAS initial condition results in an Eta

skill dramatically increased compared to that of forecasts initialized by EDAS; see, e.g., page 44 of Mesinger (2004). In other words, EDAS was in fact quite detrimental to the Eta skill compared to a simple space interpolation off the GDAS, something that would have been available operationally had the GFS been running first, or had the two been running at the same time, neither of the two being in place at NCEP. This surprising result was assumed to be due to difficulties EDAS developers had with the eta coordinate, but very recently a similar result was obtained with the NMM data assimilation system, GSI, even though the NMM is using the sigma coordinate. Thus, the reason for the EDAS unimpressive showing remains a mystery. The experience of the NARR project (Mesinger et al. 2006) in which EDAS was used at 3 h intervals in a continuous data assimilation mode points to a considerable level of noise out of EDAS. Presumably, a still greater level of noise should be expected following a space interpolation off another model's system, e.g., GFS. This is clearly okay as far as synoptic-type forecasts at 24 h or even 12 h are concerned; but if precipitation during the first 3 h is important, the noise cannot be harmless. Thus, for such purposes digital filtering or the Lazic Matsuno-type time filtering (Lazic 2008) should be useful.

The Eta model is used nowadays in very many countries and institutions, for a variety of purposes: operational day to day forecasting, research, applications (e.g., sand, dust and contaminant transport), and as of recently seasonal forecasting (e.g., Chou et al. 2005), and regional climate change studies (e.g., Djurdjevic and Rajkovic 2008).

The Eta code used at the previous ICTP Regional Weather Predictability and Modeling (RWPM) workshop, in 2005, is posted at http://www.cptec.inpe.br/etaweb/. The site also contains a list of upgrades that this "ICTP 2005" Eta code contains compared to the standard NCEP Eta code. An additional upgrade was available at the site but it is not available at the time of this writing: a change in the scheme to do temperature advection along sloping eta surfaces. This change eliminated a problem of occasional too low temperatures in some mountain basins, identified as due to unrealistic vertical advection from below ground when a centered finite difference scheme is used. This change will be included in the ICTP 2008 code.

In addition, the following new features are planned to be available in the ICTP 2008 code:

• An option to use piecewise linear vertical advection (Mesinger and Jovic 2002) of the dynamical variables, velocity and temperature, instead of the finite difference scheme in use in the standard Eta code. Note that this makes the Eta dynamics very nearly finite volume;

• An option to have vertical momentum flux included within the Kain-Fritsch convection scheme;

• A further refinement of the BMJ convection, as explained in greater detail in a separate write up ("An Essay on the Eta Cumulus Convection (BMJ) Scheme");

• Output of the 10 m winds at the wind points, as opposed to the standard Eta postprocessing scheme in which 10 m winds are output at "h" (pressure) points (the issue brought up and code written by S. Morelli, University of Modena and Reggio E., Italy).

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