User's Guide for the NMMB Core of the NOAA Environmental Modeling System (NEMS)

Acknowledgement

If NEMS-NMMB was used for work resulting in a publication, or significant help was provided via the NEMS-NMMB helpdesk for work resulting in a publication, please acknowledge the Developmental Testbed Center Mesoscale Modeling Team.

For referencing this document please use:
Community NEMS-NMMB Users' Guide V1.1, 98 pp. [available online at http://www.dtcenter.org/nems-nmmb/users/nmmb_users_guide_v1.1.pdf]

Chapter 1: Overview

Table of Contents

Introduction

The Nonhydrostatic Multi-Scale Model on the B grid (NMMB) core of the NOAA Enviromental Modeling System (NEMS) was developed by the National Oceanic and Atmospheric Adminstration (NOAA) National Center for Environmental Prediction (NCEP). The NMMB is designed to be a flexible, state-of-the-art atmospheric simulation system that is portable and efficient on available parallel computing platforms. The NMMB is suitable for use in a broad range of applications, ranging from meters to thousands of kilometers, including:

- Regional and global real-time NWP
- Regional and global forecast research
- Regional and global climate research
- Parameterization research
- Coupled-model applications
- Teaching

NOAA/NCEP/DTC are currently maintaining and supporting the NEMS components that include:

- NEMS Earth System Modeling Framework (ESMF) and software components
- NEMS Preprocessing System (NPS)
- NMMB dynamics and physics solver, including one-way, two-way, stationary and movable nesting options
- Post-processing utilities and scripts for producing images in several graphics programs.

Users interested in conducting data assimilation experiments with the NEMS-NMMB may use the Gridpoint Statistical Interpolation (GSI) data assimilation system. GSI is the data assimilation system in use with the operational implementation of the NEMS-NMMB model, known as the North American Mesoscale (NAM) forecast system, as well as all other atmospheric numerical weather prediction systems run at NOAA/NCEP. GSI is another DTC-supported project and more information on GSI and its capabilities may be found here:

http://www.dtcenter.org/com-GSI/users/

Other components of the NEMS system will be supported for community use in the future, depending on interest and available resources.

The NEMS System Program Components

Figure 1 shows a flowchart for NEMS. As shown in the diagram, NEMS consists of three major components:

- NEMS Preprocessing System (NPS)
- NMMB solver
- Postprocessor utilities and graphics tools including Unified Post Processor (UPP)

NEMS Preprocessing System (NPS)

This program is used for real-data simulations. Its functions include:

- Defining the simulation domain;
- Interpolating terrestrial data (such as terrain, land-use, and soil types) to the simulation domain;
- De-gribbing and interpolating initial and/or boundary meteorological data from other models to the simulation domain and the model coordinate.

NEMS-NMMB

The key features of NEMS-NMMB are:

- Regional and global options.
- Fully compressible, non-hydrostatic model with a hydrostatic option (Janjic, 2003a, Janjic and Gall 2012).
- Hybrid (sigma-pressure) vertical coordinates.
- Arakawa B-grid.
- Forward-backward scheme for horizontally propagating fast waves, implicit scheme for vertically propagating sound waves, Adams-Bashforth Scheme for horizontal advection, and Crank-Nicholson scheme for vertical advection. The same time step is used for all terms.
- Conservation of a number of first and second order quantities, including energy and enstrophy (Janjic 1984, Janjic and Gall 2012).
- Full physics options for land-surface, planetary boundary layer, gravity wave drag, atmospheric and surface radiation, microphysics, and cumulus convection.
- Optional digital filter initialization, including the ability to use radar reflectivity-derived temperature tendencies to facilitate the initiation/initialization of deep

convective storms.

- One-way and two-way nesting with multiple nests.
- Movable nests, suitable for tropical storm applications.
- Ability to run the model in regional or global modes.

The NPS code contains several subutilities with executables that handle individual preprocessing tasks and NEMS-NMMB contains a numerical integration program (***NEMS.x***).

Unified Post Processor (UPP)

This program can be used to post-process NMMB forecasts and was designed to:

- Interpolate the forecasts from the model's native vertical coordinate to NWS standard output levels.
- Destagger the forecasts from the staggered native grid to a regular non-staggerred grid.
- Compute diagnostic output quantities.
- Output the results in NWS and WMO standard GRIB1 and GRIB2.

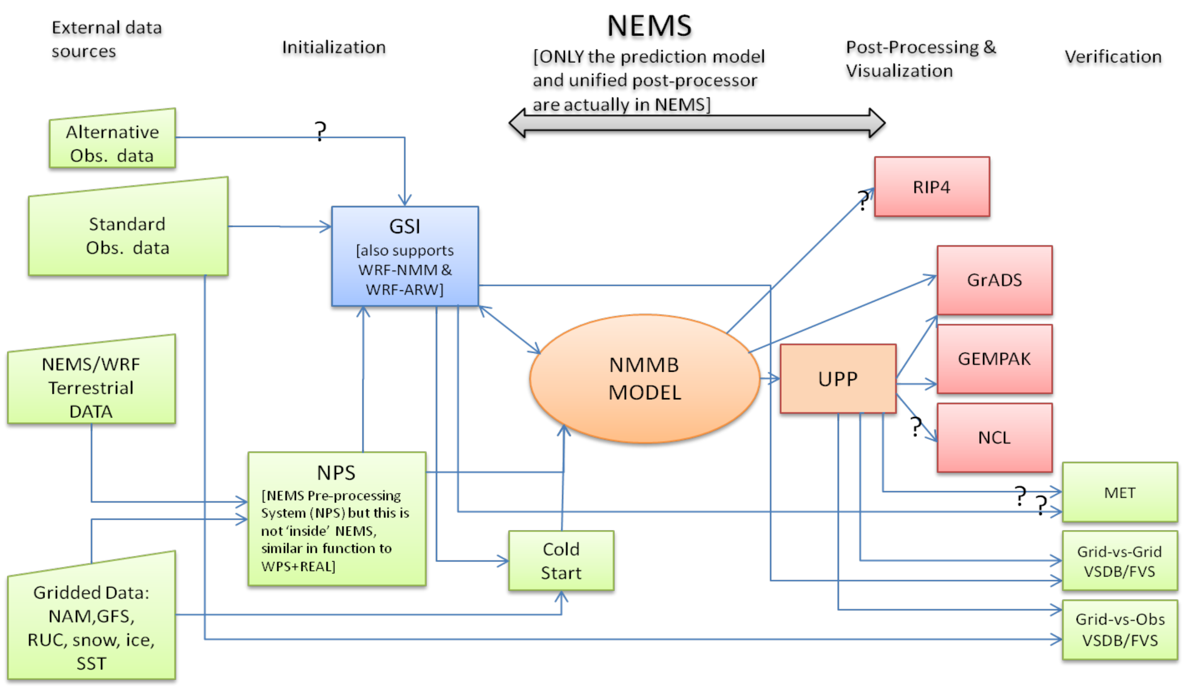


Figure 1: Flow chart for NMMB, including post-processing and visualization tools that can be obtained separately.

Chapter 2: Software Installation

Table of Contents

Introduction

The NEMS-NMMB model can only be built for shared- and distributed-memory (OpenMP and MPI) environments. All required libraries are presently available on the few supercomputers currently supporting NEMS installation. Versions 1.0 and greater include source code and compilation instructions for the NCEP libraries, which may be used to build NEMS-NMMB on other platforms.

Required Compilers and Scripting Languages

NEMS System Software Requirements

NEMS is written in Fortran 2003. Ancillary programs that perform file parsing and file construction, both of which are required for default building of the NEMS modeling code, are written in C. Thus, Fortran and C compilers are required. Additionally, the NEMS build mechanism uses several scripting languages: including C-shell and Bourne shell. The only traditional UNIX text/file processing utility used is: ***make.*** See Chapter 6: NEMS Software (Required Software) for a more detailed listing of the necessary pieces for the NEMS build.

NPS Software Requirements

The NEMS Preprocessing System (NPS) requires the same Fortran and C compilers used to build the NEMS. NPS makes direct calls to the MPI libraries for distributed memory message passing. Similar to NEMS NPS can be built with both openMP and MPI.

The user may want their system administrator to install the MPI libraries. To determine whether MPI is available on your computer system, try typing:

> ***which mpif90***
> ***which mpicc***
> ***which mpirun***

If all of these executables are defined, MPI is probably already available. The MPI ***lib/***, ***include/***, and ***bin/*** need to be included in the user's path.

UNIX Environment Settings

For the Yellowstone supercomputer, path names for the compilers and most libraries are pre-loaded. For example, on Yellowstone, typing ***module list*** results in:

Currently Loaded Modules:
 1) ncarenv/1.0 2) ncarbinlibs/1.1 3) intel/12.1.5 4) ncarcompilers/1.0
 5) netcdf/4.3.0

Building the NEMS System for the NMMB

Obtaining and Opening the NEMS Package

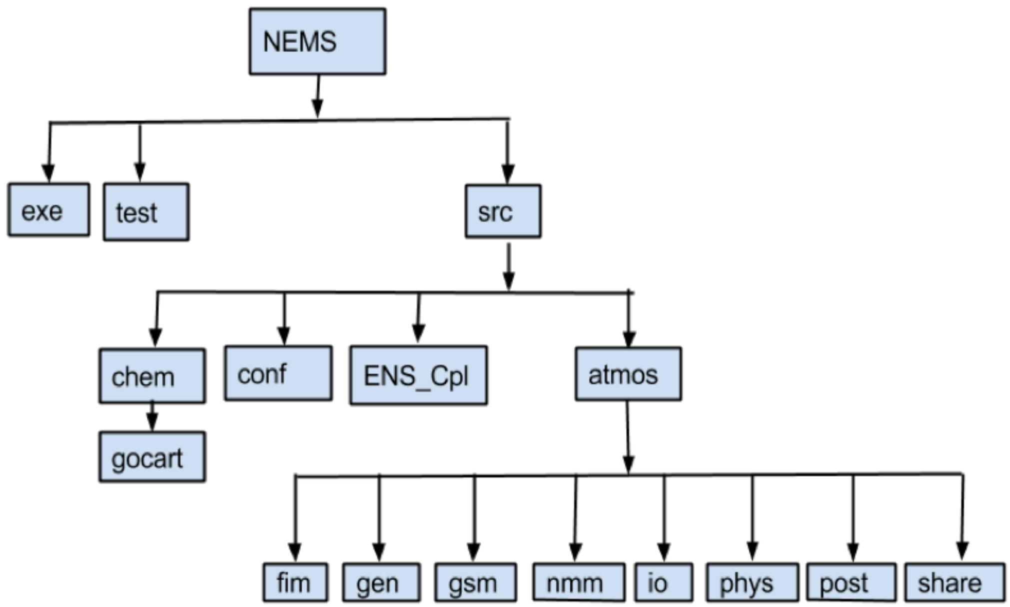
The NEMS NMMB source code file may be downloaded from:
http://www.dtcenter.org/nems-nmmb/users/downloads/index.php

Note: Always obtain the latest version of the code if you are not trying to continue a pre-existing project.

Once the ***tar*** file is obtained, ***gunzip*** and ***untar*** the file:

> ***tar –zxvf DTC_nems_v1.0.tar.gz***

The NEMS file structure contains directories presented in the following directory tree diagram:



How to Configure and Compile NEMS for the NMMB core on the Yellowstone supercomputer

The esmf library must be loaded in order to install NMMB by typing

module load esmf
module load esmf-6.3.0rp1-ncdfio-mpi-O

(Note that both module load commands are necessary)

Then continue with the following commands:

cd /NEMS/src
and run:
./configure 6_yellowstone

make nmm > & log.nmm &

When the compilation is successful, confirm the existence of:

../exe/NEMS.x

To remove all object files and executables, type:

make clean

More details on the NEMS NMMB core, physics options, and running the model can be found in Chapter 5. Regional NMMB uses input data created using the NPS code (see Chapter 3), but global NMMB does not need input data from NPS.

Building the NEMS Preprocessing System (NPS)

How to Install, Configure, and Compile the NPS

The NEMS Preprocessing System (NPS) uses a build mechanism similar to that used by the WPS. GRIB Edition 2 libraries must be installed for the ***ungrib*** program. Additional libraries are needed for ***geogrid*** and ***metgrid***. The NPS files may be downloaded from:

http://www.dtcenter.org/nems-nmmb/users/downloads/fur.php

At this point, a listing of the current working directory should at least include the directory N***PS***/. Change to the NPS directory and issue the ***conf*** command followed by the ***compile*** command, as shown below.

> ***cd NPS/***
>
> ***./conf yellowstone***
>
> ***./configure <<selection option 5 for yellowstone>>***
>
> ***./compile >& log.nps &***

After issuing the ***compile*** command, a listing of the current working directory should reveal symbolic links to executables for each of the four NPS programs: ***geogrid.exe***, ***ungrib.exe***, ***metgrid.exe,*** and ***nemsinterp.exe***, if the NPS software was successfully installed. If any of these links do not exist, check the compilation output in ***log.nps*** to see what went wrong.

Thus, a listing of the NPS root directory should include:

arch/
build.scr
clean
compile
conf
configure
configure.nps
configure.nps.backup

dio/
geogrid/
geogrid.exe -> geogrid/src/geogrid.exe
link_grib.csh
metgrid/
metgrid.exe -> metgrid/src/metgrid.exe
nemsinterp/
nemsinterp.exe -> nemsinterp/src/nemsinterp.exe
README_NPS
run_geo.ll
run_geo_met.ll
run_met.ll
run_nemsinterp.ll
run_nemsinterp.ll_fromload
run_nemsinterp.ll_simple
run_ungrib.ll
run_ungrib.ll_input
run_ungrib.ll_old
run_ungrib.ll_ruc
ungrib/
ungrib.exe -> ungrib/src/ungrib.exe
ungribp.exe -> ungrib/src/ungribp.exe
util/
Vtable

More details on the functions of the NPS and how to run it can be found in Chapter 3.

How to Configure and Compile NEMS for the NMMB Core on Individual Computer Systems

Compiling with Portable Libraries

Prior to the installation of NEMS on individual computer systems, it is necessary to compile a standalone version of the NCEP support libraries. These libraries include the current versions of: BACIO, BUFR, CRTM, G2TMPL, G2 GSDCLOUD, IP, NEMSIO, SFCIO, SIGIO, SP, W3EMC, and W3NCO. These libraries, along with NETCDF are sufficient to build the NEMS code.

Building the NCEP Libraries

1. **Set the environment for the compiler:** If not already done so, set the necessary paths for using your selected compiler, such as loading the appropriate modules or modifying the necessary paths. Currently only the Intel and PGI Fortran compilers are supported.

2. **Build the Libraries**

  a. **Place the tar file where you wish to install the libraries**
     i. **tar –zxvf nceplibs.tar.gz**
  b. **Go to the top level of the library directory**
     i. cd nceplibs/
  c. **Run the configure script**
     i. ./configure
     ii. Select option closest to your system
     iii. Hand edit the build configuration file configure.libs as needed
  d. **Run the compile script and pipe the output into a log file**
     i. ./compile > build.log
  e. **Confirm that the libraries have been successfully built.**
     i. Search the log file for the word "Error."
     ii. Confirm that the libraries listed above are contained within the libs/ directory.

Building NEMS with Standalone Libraries

A generic configuration file was created for building NEMS on platforms that lack the NCEP support libraries. It is the configure option called "6_dtc." It assumes ESMF v6.3.0r has been loaded. The script also assumes that the libraries will have the naming convention used by the NCEP libraries tarball, which is "library name" _ "library version" _ "precision," where the precision suffix is optional. Any deviation form this naming convention will require modifying the rules in DTC_nmmb_v1.0/src/conf/configure.nems.Linux.intel.dtc

To build NEMS with the standalone libraries use the following steps.

1. Build and install the standalone libraries.
2. Set the environmental variable DTC_LIB to the location of the standalone libraries. For example on csh/ksh systems use the command
   a. setenv DTC_LIB PATH_TO_LIBRARIES
   b. export DTC_LIB=PATH_TO_LIBRARIES
3. Confirm that the environment variable NETCDF points to the location of a valid installation of the NETCDF library.
4. cd DTC_nmmb_v1.0/src
5. ./configure 6_dtc
6. make nmm >& log.nmm&
7. Confirm executable existence in ../exec/NEMS.x

Building NMMB with Standalone Libraries

The build process for the NMMB_init code requires four additional libraries than those provided by the set of standalone NCEP libraries. They are jasper, png, z, and landsfcutil. The default build rules assume that all four are stored in the same location and that the path to that the environmental variable NEMS_DIR is set to its location. If these libraries on your system are not co-located, it may be necessary to edit the configuration file DTC_nmmb_v1.0/NPS/arch/ preamble.linux_dtc and update the four library paths

- LANDSFCUTIL_INC
- LANDSFCUTIL_LIBS
- COMPRESSION_INC
- COMPRESSION_LIBS

to the correct locations.

To build NMMB_init with the standalone NCEP libraries use the following steps:

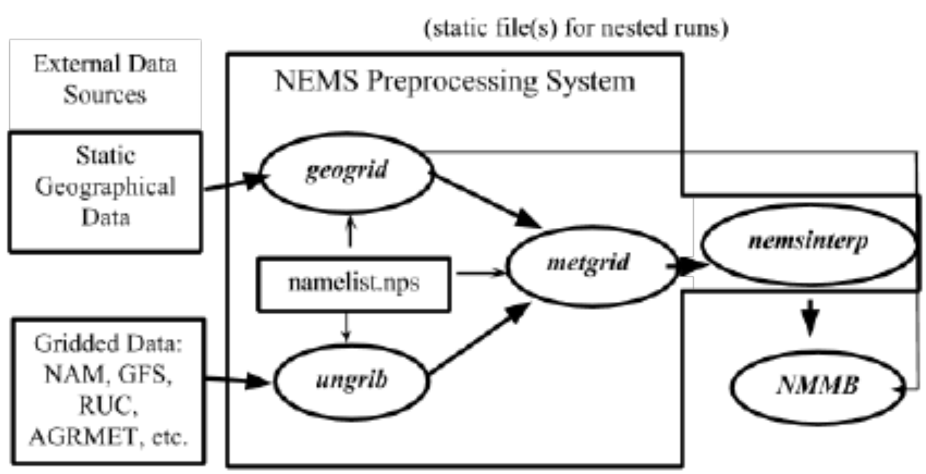
1. Set two environmental variables to the locations of external libraries
    a. Set DTC_LIB to the location of the standalone libraries NCEP libraries
    b. Set NEMS_DIR to the location of the additional libraries
        i. Jasper
        ii. Png
        iii. Z
        iv. landsfcutil
2. cd DTC_nmmb_v1.0/NPS
3. ./conf linux_dtc
4. ./configure
5. ./compile >& log.nps &
6. Confirm that the four executables exist:
    a. ungrib.exe
    b. ungribp.exe
    c. geogrid.exe
    d. nemsinterp.exe

Chapter 3: NEMS Preprocessing System (NPS)

Table of Contents

Introduction

The NEMS Preprocessing System (NPS) is a set of four programs whose collective role is to prepare the model for real-data simulations. Each of the programs performs one stage of the preparation: *geogrid* defines model domains and interpolates static geographical data to the grids; *ungrib* extracts meteorological fields from GRIB-formatted files; and *metgrid* horizontally interpolates the meteorological fields extracted by ungrib to the model grids defined by geogrid. The work of vertically interpolating meteorological fields to the sigma-pressure hybrid coordinate is performed within the *nemsinterp* program.



The data flow between the programs of the NPS is shown in the figure above. Each of the NPS programs reads parameters from a common namelist file, as shown in the figure. This namelist file has separate namelist records for each of the programs and a shared namelist record, which defines parameters that are used by more than one NPS program. Not shown in the figure are additional table files that are used by individual programs. These tables provide additional control over the programs' operation, though they generally do not need to be changed by the user. The GEOGRID.TBL, METGRID.TBL, and Vtable files are explained later in this document, though for now, the user need not be concerned with them.

The build mechanism for the NPS, which is very similar to the build mechanism used by the WRF model, provides options for compiling the NPS on a variety of platforms. When MPI libraries and suitable compilers are available, the metgrid and geogrid programs may be compiled for distributed memory execution, which allows large model domains to be processed in less time. The work performed by the ungrib program is generally not amenable to parallelization, unless processing GFS spectral data. However, a parallel version of the ungrib program (ungribp.exe) exists to process multiple times concurrently, and will be discussed later.

Function of Each NPS Program

The NPS consists of four independent programs: *geogrid*, *ungrib*, *metgrid,* and *nemsinterp*. Also included in the NPS are several utility programs, which are described in the section on utility programs. A brief description of each of the three main programs is given below, with further details presented in subsequent sections.

Program geogrid

The purpose of geogrid is to define the simulation domains, and interpolate various terrestrial data sets to the model grids. The simulation domains are defined using information specified by the user in the "geogrid" namelist record of the NPS namelist file, namelist.nps. In addition to computing the latitude, longitude, geogrid will interpolate soil categories, land use category, terrain height, annual mean deep soil temperature, monthly vegetation fraction, monthly albedo, maximum snow albedo, and slope category to the model grids by default. Global data sets for each of these fields are provided through the NEMS download page, and, because these data are time-invariant, they only need to be downloaded once. Several of the data sets are available in only one resolution, but others are made available in resolutions of 30", 2', 5', and 10'; here, " denotes arc seconds and ' denotes arc minutes. The user need not download all available resolutions for a data set, although the interpolated fields will generally be more representative if a resolution of data near to that of the simulation domain is used. However, users who expect to work with domains having grid spacings that cover a large range may wish to eventually download all available resolutions of the static terrestrial data.

Besides interpolating the default terrestrial fields, the geogrid program is general enough to be able to interpolate most continuous and categorical fields to the simulation domains. New or additional data sets may be interpolated to the simulation domain through the use of the table file, GEOGRID.TBL. The GEOGRID.TBL file defines each of the fields that will be produced by geogrid; it describes the interpolation methods to be used for a field, as well as the location on the file system where the data set for that field is located.

The 'ncep_processing' option, within the NPS namelist under the 'geogrid' section, is set to 'true' as a default and is the recommended setting. This flag is necessary for moving nests and in order to properly generate gravity wave drag fields from the sub-grid scale topography information. When 'ncep_processing' is set to 'true', additional flags are available in a separate namelist: NPS/geogrid/***testb.nml*** (note that there are different versions of this file depending on which machine is being used). This file controls paths to static file inputs (topography, etc) and controls topography smoothing. The static file inputs are distinctly different than those called when 'ncep_processing' is set to false under the geogrid portion of the namelist file. Note that this file must be linked to fort.81 prior to running NPS. The following is a list of parameters found in testb.nml for the Yellowstone supercomputer:

```
&soil_tiling
 max_soil_tiles=1
 soil_tile_threshold=0.05
 default_soil_category=7
 num_soil_groups = 5
!----------------------------------------------
! soil groups
! 1 - sand  - cats 1,2,3
! 2 - silt  - cats 4,5,8
! 3 - loam  - cats 6,7,9
! 4 - clay  - cats 10,11,12
! 5 - other - cats 13,15,16
!----------------------------------------------
 soil_groups = 1,1,1,2,2,3,3,2,3,4,4,4,5,9,5,5
/

!----------------------------------------------------------
! smooth = 1, peak smoothing with 'num_smooth_passes1' passes.
! smooth = 2, smoother/desmoother with 'num_smooth_passes2' passes.
! smooth = 3, both (1, then 2)
! both options smooth the lateral boundaries in
! the same heavy-handed manner.
!----------------------------------------------------------

&lsmask_orog_tiling
 lsmask_aavg=.true.
 lsmask_tiles=.false.
 lsmask_tile_threshold=0.0
 orog_gwd_tiles=.true.
 max_orog_tiles=1
 orog_bin_width=300.0
```

```
 orog_tile_threshold=0.05
 smooth=3
 num_smooth_passes1=6
 num_smooth_passes2=4
/

&input_data
 leaf_area_idx_file=""
 gfrac_file="/meso/mirror/wx20py/geog/green.0.144.bin"
 mxsnow_alb_file="/meso/mirror/wx20py/geog/mxsno.1.0.bin"
 roughness_file=""
 slopetype_file="/meso/mirror/wx20py/geog/slope.1.0.bin"
 snowfree_albedo_file="/meso/mirror/wx20py/geog/albedo.1.0.bin"
 soiltype_tile_file="/meso/mirror/wx20py/geog/topsoil_fao.30s"
 substrate_temp_file="/meso/mirror/wx20py/geog/tbot.1.0.bin"
 vegtype_tile_file="/meso/mirror/wx20py/geog/vegtype_usgs.30s"
 lsmask_file="/meso/mirror/wx20py/geog/gl-latlong-1km-
landcover.bsq.fixed"
 orog_file="/meso/mirror/wx20py/geog/terrain_usgs.30s"
/

&output_data
grib2=NCEP_PROC_GRIB2
/
```

Output from geogrid can be written in both binary and netCDF format. Limited binary output content from geo_nmb.d01.dio can be viewed using NPS/dio/diodump.exe, and NetCDF output can be viewed in ncview.

Program ungrib

The ungrib program reads GRIB files, "degribs" the data, and writes the data in a simple format, called the intermediate format (see the section on writing data to the intermediate format for details of the format). The GRIB files contain time-varying meteorological fields and are typically from another regional or global model, such as NCEP's NAM or GFS models. The ungrib program can read GRIB Edition 1 and GRIB Edition 2 files.

GRIB files typically contain more fields than are needed to initialize NMMB. Both versions of the GRIB format use various codes to identify the variables and levels in the GRIB file. Ungrib uses tables of these codes – called Vtables, for "variable tables" – to define which fields to extract from the GRIB file and write to the intermediate format. Details about the codes can be found in the WMO GRIB documentation and in documentation from the originating center. Vtables for common GRIB model output files are provided with the ungrib software.

Vtables are provided for NAM 104 and 212 grids, the NAM AWIP format, GFS, the NCEP/NCAR Reanalysis archived at NCAR, RUC (pressure level data and hybrid coordinate data), Users can create their own Vtable for other model output using any of the Vtables as a template; further details on the meaning of fields in a Vtable are provided in the section on creating and editing Vtables.

Program metgrid

The metgrid program horizontally interpolates the intermediate-format meteorological data that are extracted by the ungrib program onto the simulation domains defined by the geogrid program. The interpolated metgrid output can then be ingested by the NEMS nemsinterp program. The range of dates that will be interpolated by metgrid are defined in the “share” namelist record of the NPS namelist file, and date ranges must be specified individually in the namelist for each simulation domain. Since the work of the metgrid program, like that of the ungrib program, is time-dependent, metgrid is run every time a new simulation is initialized.

Control over how each meteorological field is interpolated is provided by the METGRID.TBL file. The METGRID.TBL file provides one section for each field, and within a section, it is possible to specify options such as the interpolation methods to be used for the field, the field that acts as the mask for masked interpolations, and the grid staggering (e.g., H, V in NMMB) to which a field is interpolated.

Output from metgrid can written in NEMSIO binary or netCDF format. Metgrid output can be visualized using external software packages, including GrADS, and UPP.

Program nemsinterp

The ***nemsinterp.exe*** portion of the code generates initial and boundary conditions for the NMMB model (***NEMS.x***).

The ***nemsinterp*** program performs the following tasks:

- Reads data from the namelist (***namelist.nps***)
- Reads input data from the first three programs of the NEMS Preprocessing System (NPS)
- Prepares soil fields for use in the model (usually vertical interpolation to the requested levels)
- Checks to verify soil categories, land use, land mask, soil temperature, and sea surface temperature are all consistent with each other
- Vertically interpolates to the models computational surfaces.
- Generates initial condition files
- Generates lateral condition files

The ***nemsinterp.exe*** program may be run as a distributed memory job, but there may be no computational speed up since this program relies heavily on I/O and does few computations.

Initialization from other model output

The ***nemsinterp.exe*** code uses data files provided by the metgrid, ungrib, and geogrid NPS programs as input. The data processed by the NPS typically come from a previously run, large-scale forecast model. The original data are generally in “GriB” format and are ingested into the NPS by first using ***ftp*** to retrieve the raw GriB data from one of the national weather agencies anonymous ftp sites.

For example, a forecast from 2005 January 23 0000 UTC to 2005 January 24 0000 UTC which has original GriB data available at 3h increments will have the following files previously generated by the NPS metgrid component:

met_nmb.d01.2005-01-23_00:00:00
met_nmb.d01.2005-01-23_03:00:00
met_nmb.d01.2005-01-23_06:00:00
met_nmb.d01.2005-01-23_09:00:00
met_nmb.d01.2005-01-23_12:00:00
met_nmb.d01.2005-01-23_15:00:00
met_nmb.d01.2005-01-23_18:00:00
met_nmb.d01.2005-01-23_21:00:00
met_nmb.d01.2005-01-24_00:00:00

The convention is to use "***met_nmb"*** to signify data that are output from the NPS metgrid step and used as input into the ***nemsinterp.exe*** program, the final step in the NPS. The "***d01"*** part of the name is used to identify to which domain this data refers. The trailing characters are the date, where each metgrid output file has only a single time-slice of processed data.

The following statements apply to these data:

- The data has already been horizontally interpolated to the correct grid-point staggering for each variable, and the winds are correctly rotated to the model map projection.
- 3-D meteorological data required from the NPS: ***pressure***, ***u***, ***v***, ***temperature***, ***relative humidity***, ***geopotential height***
- Optional 3-D hydrometeor data may be provided to the real program at run-time, but these fields will not be used in the coarse-grid lateral boundary file. Fields such as, mixing ratio for rain, cloud, snow, ice, graupel, hail, and number concentration are eligible for input from metgrid output files.
- 3D soil data: ***soil temperature***, ***soil moisture***, ***soil liquid***
- 2D meteorological: ***sea level pressure***, ***surface pressure***, ***surface u and v***, ***surface temperature***, ***surface relative humidity***, ***input elevation***
- 2-D meteorological optional: ***sea surface temperature***, ***physical snow depth***, ***water equivalent snow depth***
- 2D static data for the physical surface: ***terrain elevation***, ***land use categories***, ***soil texture categories***, ***temporally-interpolated monthly data***, ***land sea mask***, ***elevation of the input model's topography***
- 2D static data for the projection: ***map factors***, ***Coriolis***, ***projection rotation***, ***computational latitude***
- constants: ***domain size***, ***grid distances***, ***date***

- All 3-D meteorological data (wind, temperature, height, moisture, pressure) must have the same number of levels, and variables must have the exact same levels. For example, it is not acceptable to have more levels for temperature (for example) than height. Likewise, it is not acceptable to have an extra level for the horizontal wind components, but not for moisture.

Running the NPS

There are essentially four main steps to running the NEMS Preprocessing System:

1. Define a model coarse domain and any nested domains with *geogrid*.
2. Extract meteorological fields from GRIB data sets for the simulation period with *ungrib*.
3. Horizontally interpolate meteorological fields to the model domains with *metgrid*.
4. Vertically interpolate meteorological fields to the model domains and write out initial and lateral boundary condition files with *nemsinterp*

When multiple simulations are to be run for the same model domains, it is only necessary to perform the first step once; thereafter, only time-varying data need to be processed for each simulation using steps two and three. Similarly, if several model domains are being run for the same time period using the same meteorological data source, it is not necessary to run ungrib separately for each simulation. Below, the details of each of the three steps are explained.

Step 1: Define model domains with geogrid

In the root of the NPS directory structure, symbolic links to the programs geogrid.exe, ungrib.exe, metgrid.exe, and nemsinterp.exe should exist if the NPS software was successfully installed. In addition to these four links, a namelist.nps file should exist. Thus, a listing in the NPS root directory should look something like:

```
      > ls
-rwxrwxrwx 1 build.scr*
-rwxrwxrwx 1 clean
-rwxrwxrwx 1 compile
-rwxrwxrwx 1 conf*
-rwxrwxrwx 1 configure
-rwxrwxrwx 1 configure.nps
drwxrwsrwx 3 dio/
drwxrwsrwx 4 geogrid/
lrwxrwxrwx 1 geogrid.exe -> geogrid/src/geogrid.exe
-rwxrwxrwx 1 link_grib.csh
drwxrwsrwx 4 metgrid/
lrwxrwxrwx 1 metgrid.exe -> metgrid/src/metgrid.exe*
-rwxr-xr-x 1 namelist.nps
drwxrwsrwx 4 nemsinterp/
lrwxrwxrwx 1 nemsinterp.exe -> nemsinterp/src/nemsinterp.exe*
drwxrwsrwx 5 ungrib/
lrwxrwxrwx 1 ungrib.exe -> ungrib/src/ungrib.exe*
drwxrwsrwx 4 util/
```

```
-rwxrwxrwx 1 Vtable
```

The model coarse domain and any nested domains are defined in the "geogrid" namelist record of the namelist.nps file, and, additionally, parameters in the "share" namelist record need to be set. An example of these two namelist records is given below, and the user is referred to the description of namelist variables for more information on the purpose and possible values of each variable.

```
&share
 wrf_core = 'NMB',
 max_dom = 1,
 start_date = '2008-03-24_12:00:00','2008-03-24_12:00:00',
 end_date   = '2008-03-24_18:00:00','2008-03-24_12:00:00',
 interval_seconds = 21600,
 io_form_geogrid = 1
 debug_level = 50
/

&geogrid
 parent_id         =   1,   1,
 parent_grid_ratio =   1,   3,
 i_parent_start    =   1,  31,
 j_parent_start    =   1,  17,
 e_we              =  74, 112,
 e_sn              =  61,  97,
 geog_data_res     = '10m','2m',
 dx = 0.289153,
 dy = 0.287764,
 map_proj = 'rotated_ll',
 ref_lat   =  34.83,
 ref_lon   = -81.03,
 geog_data_path = '/glade/p/ral/jnt/DATA_nems_init/geog'
 opt_geogrid_tbl_path='/glade/p/ral/jnt/NMMB_Tutorial/static'
 ncep_processing = .false.
 ncep_proc_path = '/glade/p/ral/jnt/DATA_nems_init/geog'
 ncep_proc_prefix = 'b'
 ncep_proc_domain_type = 'bgrid'
 do_gwd = .false.
 just_last = .false.
 use_igbp = .false.
ncep_proc_grib2 = NCEP_PROC_GRIB2
movable_nests = MOVE_NESTS
/
```

To summarize a set of typical changes to the "share" namelist record relevant to geogrid, the dynamical core must first be selected with `wrf_core`. If NPS is being run for an NMMB simulation, `wrf_core` should be set to `'NMB'`. After selecting the dynamical core, the total number of domains must be chosen with `max_dom`. Since geogrid produces only time-independent data, the `start_date`, `end_date`, and `interval_seconds` variables are ignored by geogrid. Optionally, a location (if not the default, which is the current working directory) where domain files should be written to may be indicated with the `opt_output_from_geogrid_path` variable, and the format of these domain files may be changed with `io_form_geogrid`.

In the "geogrid" namelist record, the projection of the simulation domain is defined, as are the size and location of all model grids. The map projection to be used for the model domains is specified with the `map_proj` variable.

Besides setting variables related to the projection, location, and coverage of model domains, the path to the static geographical data sets must be correctly specified with the `geog_data_path` variable. Also, the user may select which resolution of static data geogrid will interpolate from using the `geog_data_res` variable, whose value should match one of the resolutions of data in the GEOGRID.TBL. Possible resolutions of the data include `'30s'`, `'2m'`, `'5m'`, and `'10m'`, corresponding to 30-arc-second data, 2-, 5-, and 10-arc-minute data.

Depending on the value of the `wrf_core` namelist variable, the appropriate GEOGRID.TBL file must be used with geogrid, since the grid staggerings that NPS interpolates to differ between dynamical cores. For the NMMB, the GEOGRID.TBL.NMB file should be used. Selection of the appropriate GEOGRID.TBL is accomplished by linking the correct file to GEOGRID.TBL in the geogrid directory (or in the directory specified by `opt_geogrid_tbl_path`, if this variable is set in the namelist).

```
> ls geogrid/GEOGRID.TBL

lrwxrwxrwx 1      15 GEOGRID.TBL -> GEOGRID.TBL.NMB
```

Having suitably defined the simulation coarse domain and nested domains in the namelist.nps file, the geogrid.exe executable may be run to produce domain files. In the case of NMMB domains, the domain files are named `geo_nmb.d0N.dio`, where `N` is the number of the nest defined in each file. Also, note that the file suffix will vary depending on the `io_form_geogrid` that is selected and that the ***following commands are used to run these executables on Yellowstone only.***

To run geogrid in serial mode, it is enough to simply execute the geogrid.exe command, however, the test cases included with NMMB provide a script, ***run_geogrid.csh***, which contains the ***mpirun.lsf geogrid.exe*** command to run geogrid in parallel. This can be done through a queuing system using ***run_geogrid.csh*** as an example shown below:

```
****************************************************************
#!/bin/csh

#BSUB -a poe                  # at NCAR: yellowstone
#BSUB -R "span[ptile=16]"     # how many tasks per node (up to 16)
#BSUB -n 1                    # number of total tasks
#BSUB -o geogrid.out          # output filename (%J to add job id)
```

```
#BSUB -e geogrid.err           # error filename
#BSUB -J geogrid               # job name
#BSUB -q premium               # queue
#BSUB -W 0:10                  # wallclock time
#BSUB -P P48503002


mpirun.lsf ./geogrid.exe
*********************************************************************
```

The script is executed as follows:
`bsub < run_geogrid.csh`

When geogrid.exe has finished running, the following message:

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!  Successful completion of geogrid.        !
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

should be printed in the file geogrid.out, and a listing of the NPS root directory (or the directory specified by `opt_output_from_geogrid_path`, if this variable was set) should show the domain files. If not, the geogrid.log file may be consulted in an attempt to determine the possible cause of failure. For more information on checking the output of geogrid, the user is referred to the section on checking NPS output.

```
> ls
-rwxr-xr-x 1     1672 clean
-rwxr-xr-x 1     3510 compile
-rw-r--r-- 1    85973 compile.output
-rwxr-xr-x 1     4257 configure
-rw-r--r-- 1     2486 configure.nps
-rw-r--r-- 1  1957004 geo_nmb.d01.dio
drwxr-xr-x 4     4096 geogrid
lrwxrwxrwx 1       23 geogrid.exe -> geogrid/src/geogrid.exe
-rw-rw-r-- 1      164 geogrid.err
-rw-rw-r-- 1    13425 geogrid.out
-rw-r--r-- 1     8765 geogrid.log
-rwxr-xr-x 1     1328 link_grib.csh
drwxr-xr-x 3     4096 metgrid
lrwxrwxrwx 1       23 metgrid.exe -> metgrid/src/metgrid.exe
-rw-r--r-- 1     1094 namelist.nps
-rw-r--r-- 1     4786 README
drwxr-xr-x 4     4096 ungrib
lrwxrwxrwx 1       21 ungrib.exe -> ungrib/src/ungrib.exe
drwxr-xr-x 3     4096 util
```

Step 2: Extracting meteorological fields from GRIB files with ungrib

Having already downloaded meteorological data in GRIB format, the first step in extracting fields to the intermediate format involves editing the "share" and "ungrib" namelist records of the namelist.nps file – the same file that was edited to define the simulation domains. An example of the two namelist records is given below.

```
&share
 wrf_core = 'NMB',
 max_dom = 1,
 start_date = '2008-03-24_12:00:00','2008-03-24_12:00:00',
 end_date   = '2008-03-24_18:00:00','2008-03-24_12:00:00',
 interval_seconds = 21600,
 io_form_geogrid = 1
/

&ungrib
 out_format = 'WPS',
/
```

In the "share" namelist record, the variables that are of relevance to ungrib are the starting and ending times of the coarse domain (`start_date` and `end_date`; alternatively, `start_year`, `start_month`, `start_day`, `start_hour`, `end_year`, `end_month`, `end_day`, and `end_hour`) and the interval between meteorological data files (interval_seconds). In the "ungrib" namelist record, the variable `out_format` is used to select the format of the intermediate data to be written by ungrib, and `'WPS'` should be specified for `out_format`. Also in the "ungrib" namelist, the user may specify a path and prefix for the intermediate files with the `prefix` variable.

After suitably modifying the namelist.nps file, a Vtable must be supplied, and the GRIB files must be linked (or copied) to the filenames that are expected by ungrib. The NPS is supplied with Vtable files for many sources of meteorological data, and the appropriate Vtable may simply be symbolically linked to the file Vtable, which is the Vtable name expected by ungrib. For example, if the GRIB data are from the GFS model, this could be accomplished with

```
> ln -s ungrib/Variable_Tables/Vtable.GFS Vtable
```

The ungrib program will try to read GRIB files named GRIBFILE.AAA, GRIBFILE.AAB, …, GRIBFILE.ZZZ. In order to simplify the work of linking the GRIB files to these filenames, a shell script, link_grib.csh, is provided. The link_grib.csh script takes a list of the GRIB files to be linked as a command-line argument. For example, if the GRIB data were downloaded to the directory /GFS, the files could be linked with link_grib.csh as follows:

```
> ls /GFS
-rw-r--r-- 1 51903308  1315100000000
-rw-r--r-- 1 59051387  1315100000003
```

```
-rw-r--r-- 1 57736244  1315100000006

> ./link_grib.csh /GFS/13151*
```

After linking the GRIB files and Vtable, a listing of the WPS directory should look something like the following:

```
> ls
-rwxr-xr-x 1     1672 clean
-rwxr-xr-x 1     3510 compile
-rw-r--r-- 1    85973 compile.output
-rwxr-xr-x 1     4257 configure
-rw-r--r-- 1     2486 configure.nps
-rw-r--r-- 1  1957004 geo_nmb.d01.dio
drwxr-xr-x 4     4096 geogrid
lrwxrwxrwx 1       23 geogrid.exe -> geogrid/src/geogrid.exe
-rw-rw-r-- 1      164 geogrid.err
-rw-rw-r-- 1    13425 geogrid.out
-rw-r--r-- 1     8765 geogrid.log
-rwxr-xr-x 1     1328 link_grib.csh
lrwxrwxrwx 1       23 GRIBFILE.AAA -> ../../GFS/1315100000000
lrwxrwxrwx 1       23 GRIBFILE.AAB -> ../../GFS/1315100000003
lrwxrwxrwx 1       23 GRIBFILE.AAC -> ../../GFS/1315100000006
-rwxr-xr-x 1     1328 link_grib.csh
drwxr-xr-x 3     4096 metgrid
lrwxrwxrwx 1       23 metgrid.exe -> metgrid/src/metgrid.exe
-rw-r--r-- 1     1094 namelist.nps
-rw-r--r-- 1     4786 README
drwxr-xr-x 4     4096 ungrib
lrwxrwxrwx 1       21 ungrib.exe -> ungrib/src/ungrib.exe
drwxr-xr-x 3     4096 util
lrwxrwxrwx 1       33 Vtable -> ungrib/Variable_Tables/Vtable.GFS
```

After editing the namelist.nps file and linking the appropriate Vtable and GRIB files, the ungrib.exe executable may be run to produce files of meteorological data in the intermediate format. As was the case for geogrid, ungrib may be run by using the test case script ***run_ungrib.csh*** (the same as ***run_geogrid.csh***, except executing ungrib.exe instead of geogrid.exe) which uses the mpirun.lsf command through a queuing system:

```
bsub < run_ungrib.csh
```

It should also be noted that a batch version of ungrib, ***ungribp.exe***, exists that enables a user to process all the time periods requested in MPI-parallel. This executable can replace ungrib.exe in the ***run_ungrib.csh*** script.

Since the ungrib program may produce a significant volume of output, it is recommended that ungrib output be redirected to a file, as in the command above. If ungrib.exe runs successfully, the following message:

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!  Successful completion of ungrib.  !
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

will be written to the end of the ungrib.out file, and the intermediate files should appear in the current working directory. The intermediate files written by ungrib will have names of the form `???:`*`YYYY-MM-DD_HH`*, where ??? is replaced with the prefix name defined in the NPS namelist file. In the sample case listed below, GFS is used. Please see the following list of files (the PATH variable is the root directory for NEMS-NMMB):

```
> ls
-rwxr-xr-x 1       1672 clean
-rwxr-xr-x 1       3510 compile
-rw-r--r-- 1      85973 compile.output
-rwxr-xr-x 1       4257 configure
-rw-r--r-- 1       2486 configure.wps
-rw-r--r-- 1    1957004 geo_nmb.d01.dio
drwxr-xr-x 4       4096 geogrid
lrwxrwxrwx 1         23 geogrid.exe -> geogrid/src/geogrid.exe
-rw-rw-r-- 1        164 geogrid.err
-rw-rw-r-- 1      13425 geogrid.out
-rw-r--r-- 1       8765 geogrid.log
lrwxrwxrwx 1         49 GEOGRID.TBL -> $PATH/static/GEOGRID.TBL
-rw-rw-r-- 1  181984600 GFS:2013-05-31_00
-rw-rw-r-- 1  181984600 GFS:2013-05-31_03
-rw-rw-r-- 1  181984600 GFS:2013-05-31_06
lrwxrwxrwx 1         23 GRIBFILE.AAA -> ../../GFS/1315100000000
lrwxrwxrwx 1         23 GRIBFILE.AAB -> ../../GFS/1315100000003
lrwxrwxrwx 1         23 GRIBFILE.AAC -> ../../GFS/1315100000006
-rwxr-xr-x 1       1328 link_grib.csh
drwxr-xr-x 3       4096 metgrid
lrwxrwxrwx 1         23 metgrid.exe -> metgrid/src/metgrid.exe
lrwxrwxrwx 1         49 METGRID.TBL -> $PATH/static/METGRID.TBL
-rw-r--r-- 1       1094 namelist.nps
-rw-r--r-- 1       4786 README
drwxr-xr-x 4       4096 ungrib
lrwxrwxrwx 1         21 ungrib.exe -> ungrib/src/ungrib.exe
-rw-r--r-- 1       1418 ungrib.log
-rw-r--r-- 1      27787 ungrib.err
-rw-r--r-- 1      27787 ungrib.out
drwxr-xr-x 3       4096 util
lrwxrwxrwx 1         33 Vtable ->
$PATH/NPS/ungrib/Variable_Tables/Vtable.GFS
```

Step 3: Horizontally interpolating meteorological data with metgrid

In the next step of running the NPS, meteorological data extracted by ungrib are horizontally interpolated to the simulation grids defined by geogrid. In order to run metgrid, the namelist.nps file must be edited. In particular, the “share” and “metgrid” namelist.nps records are of relevance to the metgrid program. Examples of these records are shown below.

```
&share
 wrf_core = 'NMB',
 max_dom = 1,
 start_date = '2008-03-24_12:00:00','2008-03-24_12:00:00',
 end_date   = '2008-03-24_18:00:00','2008-03-24_12:00:00',
 interval_seconds = 21600,
 io_form_geogrid = 5
/

&metgrid
 fg_name                      = 'GFS',
 io_form_metgrid              = 5,
/
```

Note that io_form_metgrid can be 5 for binary output or 2 for NetCDF option (the netcdf option is for geogrid and metgrid only). After this point, there is generally no need to change any of the variables in the "share" namelist record, since those variables should have been suitably set in previous steps. If the "share" namelist was not edited while running geogrid and ungrib, however, the WRF dynamical core, number of domains, starting and ending times, interval between meteorological data, and path to the static domain files must be set in the "share" namelist record, as described in the steps to run geogrid and ungrib.

In the "metgrid" namelist record, the path and prefix of the intermediate meteorological data files must be given with `fg_name`, the full path and file names of any intermediate files containing constant fields may be specified with the `constants_name` variable, and the output format for the horizontally interpolated files may be specified with the `io_form_metgrid` variable. Other variables in the "metgrid" namelist record, namely, `opt_output_from_metgrid_path` and `opt_metgrid_tbl_path`, allow the user to specify where interpolated data files should be written by metgrid and where the METGRID.TBL file may be found.

As with geogrid and the GEOGRID.TBL file, a METGRID.TBL file appropriate for the NMMB core must be linked in the metgrid directory (or in the directory specified by `opt_metgrid_tbl_path`, if this variable is set).

```
> ls metgrid/METGRID.TBL

lrwxrwxrwx 1      15 METGRID.TBL -> METGRID.TBL.NMB
```

After suitably editing the namelist.nps file and verifying that the correct METGRID.TBL will be used, metgrid may be run by using the mpirun.lsf command within ***run_metgrid.csh*** (the same as ***run_ungrib.csh*** except it is executing metgrid.exe instead of ungrib.exe) through a queuing system, such as follows:

```
bsub < run_metgrid.csh
```

If metgrid successfully ran, the message

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!  Successful completion of metgrid.        !
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

will be printed in the file metgrid.out.

After successfully running, metgrid output files should appear in the NPS root directory (or in the directory specified by `opt_output_from_metgrid_path`, if this variable was set). These files will look like the following: `met_nmb.d01.YYYY-MM-DD_HH:mm:ss.dio` in the case of NMMB domains. Here, `YYYY-MM-DD_HH:mm:ss` refers to the date of the interpolated data in each file. For nested NMMB domains, these files will appear as `met_nmb.dNN*`, where NN refers to the number of the nested domain. If `io_form_metgrid` is set to 2 in the namelist.nps file, metgrid output files will be in NetCDF format and will have an ***nc*** extension instead of ***dio***.

If these files do not exist for each of the times in the range given in the "share" namelist record, the metgrid.log file may be consulted to help in determining the problem in running metgrid.

```
> ls
-rwxr-xr-x 1       1672 clean
-rwxr-xr-x 1       3510 compile
-rw-r--r-- 1      85973 compile.output
-rwxr-xr-x 1       4257 configure
-rw-r--r-- 1       2486 configure.nps
-rw-r--r-- 1    1957004 geo_nmb.d01.dio
drwxr-xr-x 4       4096 geogrid
lrwxrwxrwx 1         23 geogrid.exe -> geogrid/src/geogrid.exe
-rw-rw-r-- 1        164 geogrid.err
-rw-rw-r-- 1      13425 geogrid.out
-rw-r--r-- 1       8765 geogrid.log
lrwxrwxrwx 1         49 GEOGRID.TBL -> $PATH/static/GEOGRID.TBL
-rw-rw-r-- 1  181984600 GFS:2013-05-31_00
-rw-rw-r-- 1  181984600 GFS:2013-05-31_03
-rw-rw-r-- 1  181984600 GFS:2013-05-31_06
lrwxrwxrwx 1         23 GRIBFILE.AAA -> ../../GFS/1315100000000
lrwxrwxrwx 1         23 GRIBFILE.AAB -> ../../GFS/1315100000003
lrwxrwxrwx 1         23 GRIBFILE.AAC -> ../../GFS/1315100000006
-rwxr-xr-x 1       1328 link_grib.csh
drwxr-xr-x 3       4096 metgrid
lrwxrwxrwx 1         23 metgrid.exe -> metgrid/src/metgrid.exe
lrwxrwxrwx 1         49 METGRID.TBL -> $PATH/static/METGRID.TBL
-rw-rw-r-- 1  194161548 met_nmb.d01.2013-05-31_00:00:00.dio
-rw-rw-r-- 1  194161548 met_nmb.d01.2013-05-31_03:00:00.dio
-rw-rw-r-- 1  194161548 met_nmb.d01.2013-05-31_06:00:00.dio
-rw-rw-r-- 1       1328 metgrid.err
-rw-rw-r-- 1     196240 metgrid.log
-rw-rw-r-- 1      44790 metgrid.out
-rw-r--r-- 1       1094 namelist.nps
```

```
      -rw-r--r-- 1       4786 README
      drwxr-xr-x 4       4096 ungrib
      lrwxrwxrwx 1         21 ungrib.exe -> ungrib/src/ungrib.exe
      -rw-r--r-- 1       1418 ungrib.log
      -rw-r--r-- 1      27787 ungrib.output
      drwxr-xr-x 3       4096 util
      lrwxrwxrwx 1         33 Vtable ->
ungrib/Variable_Tables/Vtable.GFS
```

Step 4: Vertical interpolation and write out initial/lateral boundary conditions using *nemsinterp.exe*

As was the case for geogrid, ungrib and metgrid, nemsinterp may be run by using the test case script ***run_nemsinterp.csh*** (the same as ***run_metgrid.csh***, except executing nesminterp.exe instead of metgrid.exe) which uses the mpirun.lsf command through a queuing system. The submission command is:

```
bsub < run_nemsinterp.csh
```

When ***nemsinterp.exe*** is successful, the following files, where the 0, 3, 6, etc., following the leading zeros represent forecast hours, are used by ***NEMS.x*** and should be found in the working-directory:

input_domain_01 (Initial conditions, single time level data.)
boco.0000 (Boundary condition data for multiple time steps.)
boco.0003
boco.0006 ….

To check whether the run is successful, look for "SUCCESS COMPLETE NEMSINTERP INIT" at the end of the log file.

Description of the namelist.nps Variables

SHARE section

This section describes variables that are used by more than one NPS program. For example, the `wrf_core` variable specifies whether the NPS is to produce data for he NMMB core – information which is needed by both the geogrid and metgrid programs.

1. WRF_CORE : A character string set to `NMB'` that tells the NPS which dynamical core the input data are being prepared for.

2. MAX_DOM : An integer specifying the total number of domains/nests, including the parent domain, in the simulation. Default value is 1.

3. START_YEAR : A list of MAX_DOM 4-digit integers specifying the starting UTC year of the simulation for each nest. No default value.

4. START_MONTH : A list of MAX_DOM 2-digit integers specifying the starting UTC month of the simulation for each nest. No default value.

5. START_DAY : A list of MAX_DOM 2-digit integers specifying the starting UTC day of the simulation for each nest. No default value.

6. START_HOUR : A list of MAX_DOM 2-digit integers specifying the starting UTC hour of the simulation for each nest. No default value.

7. END_YEAR : A list of MAX_DOM 4-digit integers specifying the ending UTC year of the simulation for each nest. No default value.

8. END_MONTH : A list of MAX_DOM 2-digit integers specifying the ending UTC month of the simulation for each nest. No default value.

9. END_DAY : A list of MAX_DOM 2-digit integers specifying the ending UTC day of the simulation for each nest. No default value.

10. END_HOUR : A list of MAX_DOM 2-digit integers specifying the ending UTC hour of the simulation for each nest. No default value.

11. START_DATE : A list of MAX_DOM character strings of the form `'YYYY-MM-DD_HH:mm:ss'` specifying the starting UTC date of the simulation for each nest. The `start_date` variable is an alternate to specifying `start_year`, `start_month`, `start_day`, and `start_hour`, and if both methods are used for specifying the starting time, the `start_date` variable will take precedence. No default value.

12. END_DATE : A list of MAX_DOM character strings of the form `'YYYY-MM-DD_HH:mm:ss'` specifying the ending UTC date of the simulation for each nest. The `end_date` variable is an alternate to specifying `end_year`, `end_month`, `end_day`, and `end_hour`, and if both methods are used for specifying the ending time, the `end_date` variable will take precedence. No default value.

13. INTERVAL_SECONDS : The integer number of seconds between time-varying meteorological input files. No default value.

14. IO_FORM_GEOGRID : The WRF I/O API format that the domain files created by the geogrid program will be written in. Possible options are: 5 for binary, 2 for NetCDF. When option 1 is given, domain files will have a suffix of .dio.

15. OPT_OUTPUT_FROM_GEOGRID_PATH : A character string giving the path, either relative or absolute, to the location where output files from geogrid should be written to and read from. Default value is `'./'`.

17. DEBUG_LEVEL : An integer value indicating the extent to which different types of messages should be sent to standard output. When `debug_level` is set to 0, only generally useful messages and warning messages will be written to standard output. When `debug_level` is greater than 100, informational messages that provide further runtime details are also written to standard output. Debugging messages and messages specifically intended for log files are never written to standard output, but are always written to the log files. Default value is 0.

GEOGRID section

This section specifies variables that are specific to the geogrid program. Variables in the geogrid section primarily define the size and location of all model domains, and where the static geographical data are found.

1. PARENT_ID : A list of MAX_DOM integers specifying, for each nest, the domain number of the nest's parent; for the coarsest domain, this variable should be set to 1. Default value is 1.

2. PARENT_GRID_RATIO : A list of MAX_DOM integers specifying, for each nest, the nesting ratio relative to the domain's parent. No default value.

3. I_PARENT_START : A list of MAX_DOM integers specifying, for each nest, the x-coordinate of the lower-left corner of the nest in the parent *unstaggered* grid. For the coarsest domain, a value of 1 should be specified. No default value. **For NMMB nests, see note on page 3-15.**

4. J_PARENT_START : A list of MAX_DOM integers specifying, for each nest, the y-coordinate of the lower-left corner of the nest in the parent *unstaggered* grid. For the coarsest domain, a value of 1 should be specified. No default value.

5. S_WE : A list of MAX_DOM integers which should all be set to 1. Default value is 1.

6. E_WE : A list of MAX_DOM integers specifying, for each nest, the nest's full west-east dimension. For nested domains, `e_we` must be one greater than an integer multiple of the nest's `parent_grid_ratio` (i.e., `e_ew` = *n**`parent_grid_ratio`+1 for some positive integer *n*). No default value.

7. S_SN : A list of MAX_DOM integers which should all be set to 1. Default value is 1.

8. E_SN : A list of MAX_DOM integers specifying, for each nest, the nest's full south-north dimension. For nested domains, `e_sn` must be one greater than an integer multiple of the nest's `parent_grid_ratio` (i.e., `e_sn` = *n**`parent_grid_ratio`+1 for some positive integer *n*). No default value.

Note: For NMMB, the schematic below illustrates how ***e_we*** and ***e_sn*** apply on the B-grid:

```
      V     V     V
   H     H     H
      V     V     V
   H     H     H
      V     V     V
   H     H     H
```

In this schematic, H represents mass variables (e.g., temperature, pressure, moisture) and V represents vector wind quantities. The (V) points for the eastern most column and the northern most row are "fillers", used so arrays will be completely filled (***e_we***, ***e_sn***), but the phantom column and row do not impact the integration.

9. GEOG_DATA_RES : A list of MAX_DOM character strings specifying, for each nest, a corresponding resolution or list of resolutions separated by `+` symbols of source data to be used when interpolating static terrestrial data to the nest's grid. For each nest, this string should contain a resolution matching a string preceding a colon in a `rel_path` or `abs_path` specification (see the description of GEOGRID.TBL options) in the GEOGRID.TBL file for each field. If a resolution in the string does not match any such string in a `rel_path` or `abs_path` specification for a field in GEOGRID.TBL, a default resolution of data for that field, if one is specified, will be used. If multiple resolutions match, the first resolution to match a string in a `rel_path` or `abs_path` specification in the GEOGRID.TBL file will be used. Default value is `'default'`.

10. DX : A real value specifying the grid distance in the x-direction where the map scale factor is 1. For NMMB, the grid distance is in degrees longitude. Grid distances for nests are determined recursively based on values specified for `parent_grid_ratio` and `parent_id`. No default value.

11. DY : A real value specifying the nominal grid distance in the y-direction where the map scale factor is 1. For NMMB, the grid distance is in degrees latitude. Grid distances for nests are determined recursively based on values specified for `parent_grid_ratio` and `parent_id`. No default value.

Note: For the rotated latitude-longitude grid used by NMMB, the grid center is the equator. ***DX*** and ***DY*** are constant within this rotated grid framework. However, in a true Earth sense, the grid spacing in kilometers varies slightly between the center latitude and the northern and southern edges due to convergence of meridians away from the equator. This behavior is more notable for domains covering a wide range of latitudes. Typically, ***DX*** is set to be slightly larger than ***DY*** to counter the effect of meridional convergence, and keep the unrotated, "true earth" grid spacing more uniform over the entire grid.

The relationship between the fraction of a degree specification for the B-grid and the more typical grid spacing specified in kilometers for other grids can be approximated by considering the following schematic:

```
H - DX -  H
 |         |
DY   V   DY
 |         |
H - DX -  H
```

The DX and DY refer to distances between adjacent H and V points. Assuming 111 km/degree (a reasonable assumption for the rotated latitude-longitude grid) the grid spacing in km is approximately equal to: 111.0*((DX+DY)/2).

12. MAP_PROJ : A character string specifying the projection of the simulation domain. For NMMB, a projection of `'rotated_ll'` must be specified. Default value is `'lambert'`.

13. REF_LAT : A real value specifying the latitude part of a (latitude, longitude) location whose (i,j) location in the simulation domain is known. For NMMB, `ref_lat` always gives the latitude to which the origin is rotated. No default value.

14. REF_LON : A real value specifying the longitude part of a (latitude, longitude) location whose (i, j) location in the simulation domain is known. For NMMB, `ref_lon` always gives the longitude to which the origin is rotated. For NMMB, west longitude is negative, and the value of `ref_lon` should be in the range [-180, 180]. No default value.

15. REF_X : A real value specifying the i part of an (i, j) location whose (latitude, longitude) location in the simulation domain is known. The (i, j) location is always given with respect to the mass-staggered grid, whose dimensions are one less than the dimensions of the unstaggered grid. Default value is (((`E_WE`-1.)+1.)/2.) = (`E_WE`/2.).

16. REF_Y : A real value specifying the j part of an (i, j) location whose (latitude, longitude) location in the simulation domain is known. The (i, j) location is always given with respect to the mass-staggered grid, whose dimensions are one less than the dimensions of the unstaggered grid. Default value is (((`E_SN`-1.)+1.)/2.) = (`E_SN`/2.).

17. TRUELAT1 : For NMMB, `truelat1` is ignored. No default value.

18. TRUELAT2 : For NMMB, `truelat2` is ignored. No default value.

19. STAND_LON : For NMMB, `stand_lon` is ignored. No default value.

20. GEOG_DATA_PATH : A character string giving the path, either relative or absolute, to the directory where the geographical data directories may be found. This path is the one to which `rel_path` specifications in the GEOGRID.TBL file are given in relation to. No default value.

21. OPT_GEOGRID_TBL_PATH : A character string giving the path, either relative or absolute, to the GEOGRID.TBL file. The path should not contain the actual file name, as GEOGRID.TBL is assumed, but should only give the path where this file is located. Default value is `'./geogrid/'`.

22. NCEP_PROCESSING : set to .True. for using NCEP processing required for moving nests, generally recommended.

23. NCEP_PROC_PATH: A character string giving the path, either relative or absolute.

24. NCEP_PROC_PREFIX: If NCEP_PROCESSING is true, provides a character string used in the filenames of the intermediate GRIB files (e.g., ncep_proc_prefix = 'nmmb' results in the first domain GRIB files being of the format nmmb_d01_vegfrac.grb)

25. NCEP_PROC_DOMAIN_TYPE: Set to 'b' to let the NCEP_PROCESSING code know it is dealing with a b-grid domain. Should not be changed.

26. DO_GWD: set to .TRUE. or .FALSE. True is recommended for domains coarser than about 6-8 km, and is more important for longer duration (> 48 h) forecasts and for domains containing a significant mountain range.

27. JUST_LAST: Set to .false. Functionality included to support the operational NAM nest, and if true only produces a static file for the final nest.

28 USE_IGBP: set to .TRUE. or .FALSE. True is recommended, to utilize the more modern IGBP land-use categorization dataset. If .false, the USGS land-use types are utilized.

29. NCEP_PROC_GRIB2: set to .true. or .false. True produces the intermediate GRIB files within NCEP_PROCESSING in GRIB2 format, while false produces GRIB1. Required to be true for moving nests.

30. MOVABLE_NESTS: set to .true. or .false. True produces the additional files needed for moving nests, namely the static information covering the parent domain but at the resolution of the nest.

Using Gravity Wave Drag

In order to run NMMB with gravity wave drag, NPS (geogrid) must be run with "ncep_processing=.true." and "do_gwd=.true." Then all GWD* files located in the NPS directory must be linked to the NMMB run directory prior to running the model.

UNGRIB section

1. OUT_FORMAT : A character string set to `'WPS'`; if set to `'WPS'`, ungrib will write data in the NPS intermediate format.

2. PREFIX : A character string used to describe the prefix of output files processed by ungrib (e.g., `'NAM'`, `'GFS'`).

3. SPECTRAL : If set to .true., this tells ungrib that spectral format data will be used (e.g., for GFS).

Note: NPS ungrib assumes this variable to be true when it is not included in the namelist. Therefore, it must be defined and set to .false. if not using spectral model data.

METGRID section

This section defines variables used only by the metgrid program. Typically, the user will be interested in the `fg_name` variable, and may need to modify other variables of this section less frequently.

1. FG_NAME : A list of character strings specifying the path and prefix of ungribbed data files. The path may be relative or absolute, and the prefix should contain all characters of the filenames up to, but not including, the colon preceding the date. When more than one `fg_name` is specified, and the same field is found in two or more input sources, the data in the last encountered source will take priority over all preceding sources for that field. Default value is an empty list (i.e., no meteorological fields).

2. CONSTANTS_NAME : A list of character strings specifying the path and full filename of ungribbed data files which are time-invariant. The path may be relative or absolute, and the filename should be the complete filename; since the data are assumed to be time-invariant, no date will be appended to the specified filename. Default value is an empty list (i.e., no constant fields).

3. IO_FORM_METGRID : The NMMB I/O API format that the output created by the metgrid program will be written in. Possible options are: 1 for binary; 2 for NetCDF; 3 for GRIB1. When option 1 is given, output files will have a suffix of .dio; when option 2 is given, output files will have a suffix of .nc. Default value is 2 (NetCDF).

4. OPT_OUTPUT_FROM_METGRID_PATH : A character string giving the path, either relative or absolute, to the location where output files from metgrid should be written to. The default value is the current working directory (i.e., the default value is `'./'`).

5. OPT_METGRID_TBL_PATH : A character string giving the path, either relative or absolute, to the METGRID.TBL file; the path should not contain the actual file name, as METGRID.TBL is assumed, but should only give the path where this file is located. Default value is `'./metgrid/'`.

NEMSINTERP section

This section defines variables used only by the nemsinterp program.

1. PT : The model top pressure in Pa.

2. PTSGM : Hybrid coordinate interface pressure in Pa.

3. NZ : Number of vertical layers.

4. DIRECT_TEMP : If .true., temperature is vertically interpolated like other fields. If false, temperatures are derived from layer thicknesses.

5. GLOBAL : If .true., a Global run. If false, not a global run.

6. DO_CLOUDS: If .true., generate an initial cloud condensate field. Fairly crude, but possibly better than no clouds at the initial call to radiation.

7. GRIB_SRC: If .true., source of GRIB information. GFS and NAM are the main onces that nemsinterp recognizes, and it controls which cloud-related fields are ingested.

8. BOUNDARY_FLUX: If .true., will slightly modify the winds along the boundary after vertical interpolation so the mass flux across the boundary matches that of the source model.

9. LNSH: Specifies the number of rows for which boundary information is generated for mass field variables.

10. LNSV: Specifies the number of rows for which boundary information is generated for wind field variables.

11. VCOORD: There are three styles of the pressure-sigma hybrid coordinate: 1=vc (default); 2=gfs; 3=sal(Sangster/Arakawa/Lamb)

12. COORD_LEVS: Specify nz+1 non-dimensional interface values from 0 to 1, or if left blank the code will generate a reasonable set of layers based on the pt, ptsgm, and nz values.

NPS Output Fields

Please see Appendix 1 for a list of global attributes and fields written to geogrid output files.

Chapter 4: NMMB Model

Table of Contents

Introduction

The NMMB is a fully compressible, non-hydrostatic mesoscale model with a hydrostatic option (Janjic and Gall 2012). The model uses a terrain following hybrid sigma-pressure vertical coordinate. The grid staggering uses the Arakawa B-grid. The same time step is used for all terms. The dynamics conserve a number of first and second order quantities including energy and enstrophy (Janjic 1984).

The NMMB can be run in regional and global domains and with a hierarchy of stationary and moving nests.

The NMMB code contains an initialization utility ***(NPS*** and its executables) and a numerical integration program (***NEMS.x***).

NMMB Dynamics in a Nutshell:

Time stepping

Horizontally propagating fast-waves:	Forward-backward scheme
Vertically propagating sound waves:	Implicit scheme
Horizontal advection and Coriolis terms:	Modified (Stable) Adams-Bashforth scheme
Vertical advection:	Crank-Nicholson scheme
TKE generation and dissipation:	Iterative
Water species, other tracers:	Explicit, tracer advection called every two time steps.

Advection (space) for T, U, and V

Horizontal:	Energy and enstrophy conserving, quadratic conservative, second order
Vertical:	Quadratic conservative, second order
TKE, Water species, other tracers:	Positive definite, monotone, conservative

Diffusion

Diffusion in the NMMB is categorized as lateral diffusion and vertical diffusion. The vertical diffusion in the PBL and in the free atmosphere is handled by the surface layer scheme and by a TKE based turbulence closure scheme (Janjic 1994, 1996a, 1996b, 2002a, 2002b). The lateral diffusion is formulated following the Smagorinsky non-linear approach (Janjic 1990). The control parameter for the lateral diffusion is the square of Smagorinsky constant.

Divergence Damping

The horizontal component of divergence is damped (Sadourny 1975). In addition, if applied, the technique for coupling the elementary subgrids of the B grid (Janjic 1979, JanJic and Gall 2012) also damps the divergent part of flow.

Physics Options

Microphysics

- Ferrier-Aligo: Current operational scheme used in the NMMB model. Designed for high-resolution simulations.

- Ferrier (Eta) microphysics: Used previously in NCEP models. A simple efficient scheme with diagnostic mixed-phase processes.

- New Thompson et al. scheme: A scheme with ice, snow and graupel processes suitable for high-resolution simulations.

- WSM6: 6-moment scheme with vapor, cloud ice, cloud water, graupel and snow processes.

- GFS microphysics.

Summary of Microphysics Options

Microphysics	Scheme	Reference	Added
fer_hires	Ferrier-Aligo	In progress	2014
fer	Ferrier (Eta)	Rogers, Black, Ferrier, Lin, Parrish and DiMego (2001, web doc)	2000

thompson	Thompson	Thompson, Field, Rasmussen and Hall (2008, MWR)	2009
wsm6	WSM6	Hong and Lim (2006, Journal of the Korean Meteorological Society)	-
gfs	GFS	-	-

Longwave Radiation

- GFDL scheme: An older multi-band scheme with carbon dioxide, ozone and microphysics effects.
- RRTMG scheme. A new version of RRTM. It includes the MCICA method of random cloud overlap. For major trace gases, CO2=379e-6, N2O=319e-9, CH4=1774e-9.

Shortwave Radiation

- GFDL shortwave: Two-stream multi-band scheme with ozone from climatology and cloud effects.
- RRTMG shortwave. A new shortwave scheme with the MCICA method of random cloud overlap.

Summary of Radiation Physics Options

Shortwave Radiation	Scheme	Reference	Added
rrtmg	RRTMG	Iacono et al. (2008, JGR)	2009
gfdl	GFDL	Fels and Schwarzkopf (1981, JGR)	2004

Longwave Radiation	Scheme	Reference	Added
rtmg	RRTMG	Iacono et al. (2008, JGR)	2009
gfdl	GFDL	Fels and Schwarzkopf (1981, JGR)	2004

Surface Layer

- NMMB similarity theory scheme: Based on Monin-Obukhov similarity theory with Zilitinkevich thermal roughness length (Janjic 1996b) over land and viscous sublayer (Janjic 1994) over water using similarity functions from look-up tables.

- NCEP Global Forecasting System (GFS) scheme: The Monin-Obukhov similarity profile relationship is applied to obtain the surface stress and sensible and latent heat fluxes using a formulation based on Miyakoda and Sirutis (1986) modified for very stable and unstable situations.

Land Surface

- Noah Land Surface Model: Unified NCEP/NCAR/AFWA scheme with soil temperature and moisture in four layers, fractional snow cover and frozen soil physics. Land surface evaporation has three components (direct evaporation from the soil and canopy, and transpiration from vegetation) following the formulation of Pan and Mahrt (1987).

Planetary Boundary layer

- Mellor-Yamada-Janjic scheme: Non-singular prognostic turbulent kinetic energy closure scheme with local vertical mixing.

- NCEP Global Forecast System scheme: First-order vertical diffusion scheme of Troen and Mahrt (1986) further described in Hong and Pan (1996). The PBL height is determined using an iterative bulk-Richardson approach working from the ground upward whereupon the profile of the diffusivity coefficient is specified as a cubic function of the PBL height. Coefficient values are obtained by matching the surface-layer fluxes.

Summary of PBL Physics Options

PBL	Scheme	Reference	Added
myj	MYJ	Janjic (1996a, 2002b)	2000
gfs	GFS	Hong and Pan (1996, MWR)	2005

Cumulus Parameterization

- Betts-Miller-Janjic scheme. Column moist adjustment scheme relaxing towards a well-mixed profile (bmj).

- Simplified Arakawa-Schubert scheme (sas): New mass-flux scheme with deep and shallow components and momentum transport.

Summary of Cumulus Parameterization Options

Convection	Scheme	Reference	Added
bmj	Betts-Miller-Janjic	Janjic (1994, MWR; 2000, JAS)	2002
sas	Simplified Arakawa-Schubert	Han and Pan (2011)	2005/2011

Description of Configure File Variables (configure_file_01)

The settings in the ***configure_file_01*** file are used to configure NMMB. This file should be edited to specify: dates, number and size of domains, time step, physics options, and output options. When modifying the ***configure_file_01*** file, be sure to take into account the following points:

dt: The general rule for determining the time step of the coarsest grid follows from the CFL criterion. If ***d*** is the grid distance between two neighboring points (in diagonal direction on the NMMB's B-grid), ***dt*** is the time step, and ***c*** is the phase speed of the fastest process, the CFL criterion requires that:

(c*dt)/[d/sqrt(2.)] ≤1

This gives**:**

dt ≤ d/[sqrt(2.)*c]

A very simple approach is to use ***2.25 x (grid spacing in km)*** or about ***330 x (angular grid spacing)*** to obtain an integer number of time steps per hour.

When using NPS, the coarsest grid dimensions should be set as:

im (configure_file_01) = e_ew (namelist.nps),
jm (configure_file_01) = e_sn (namelist.nps).

For example: The parent grid ***e_we (im)*** and ***e_sn (jm)*** are set up as follows:

configure_file_01	***namelist.nps***
im = 124,	***e_we*** = 124,
jm = 202,	***e_sn*** = 202

The user must specify the number of compute and i/o tasks to use for each domain by setting the following variables in the configure_file_XX.

inpes: Number of compute tasks in the I direction jnpes: Number of compute tasks in the J direction

read_groups: 0
read_tasks_per_group: 0
write_groups: 1
write_tasks_per_group: 1

For one-way nesting this is specified for each domain independently. For example, D1 may use 64 processors, and D2 use another 128. For 2-way nesting, this is more complex, as compute tasks can be shared at run-time. Please see the tutorial slides that cover nesting to understand the run-time specification of compute tasks in this case.

It is required that the number of tasks assigned when a job is submitted match exactly the number of tasks requested in the configure_file_XX files. To calculate the number of tasks to assign, use:

(inpes*jnpes)+(read_groups*read_tasks_per_group)+(write_groups*write_tasks_per_group) for EACH domain.

For example,

configure_file_01:
 inpes: 4
 jnpes: 4
 read_groups: 0
 read_tasks_per_group: 0
 write_groups: 1
 write_tasks_per_group: 1
This single-domain job would use 17 cores:

#PBS -l procs=17

Now, consider adding a one-way-nested D2 with:
 inpes: 4
 jnpes: 12
 read_groups: 0
 read_tasks_per_group: 0
 write_groups: 3
 write_tasks_per_group: 4
This domain needs 60 cores, in addition to the D1 cores above, so 77 total.

#PBS -l procs=77

Note: There MUST be at least one write_group with one write_tasks_per_group.

write_tasks_per_group: The number of ***I/O*** tasks ***(write_tasks_per_group)*** should evenly divide into the number of compute tasks in the ***J-direction*** on the grid (***nproc_y***) for optimal balance of the output workload although this is not a requirement. For example, if there are 6 compute tasks in the ***J-direction***, then ***write_tasks_per_group*** could legitimately be set to 1, 2, 3, or 6. The user needs to use a number large enough that the quilting for a given output time is finished before the next output time is reached. If one had 6 compute tasks in the ***J-direction*** (and the number in the ***I-direction*** was similar), then one would probably choose either 1 or 2 quilt tasks.

The following table provides an overview of the parameters specified in ***configure_file_01***.

Table 4. Parameters of the configure_file_01 file.

Variable Names	Value (Example)	Description
core	nmm	
&time_control		Time control
nhours_fcst	24	Run time in hours
start_year	2013	Four digit year of starting time
start_month	11	Two digit month of starting time
start_day	04	Two digit day of starting time
start_hour	00	Two digit hour of starting time
start_minute	0	Two digit minute of starting time
start_second	0	Two digit second of starting time
tstart	0	Forecast hour at the start of the NMMB integration. Set to >0 if restarting a run.
&timestep		
dt_int	20	Integer seconds
dt_num	0	Numerator of fractional second
dt_den	34	Denominator of fractional second
filt_dt_int	20	Integer seconds
filt_dt_num	0	Numerator of fractional second
filt_dt_den	34	Denominator of fractional second
&forecast length/restart/output		
minutes_history	60	History output file interval in minutes
nhours_dfini	0	
restart	false	True → A restarted run

minutes_restart	720	Frequency of restart output (minutes)
avg_max_length	3600	Time in seconds when averaged fields are reset
rst_out_00	false	True→ Write 00h history in restarted run
write_last_restart	false	True→ Write last restart file
freerun	true	True→ Original
&Grid Specifications		Domain definition
im	759	Number of points in the I direction
jm	568	Number of points in the J direction
lm	45	Number of points in the L direction
tph0d	47.500	Central geographic latitude of grid (degrees)
tlm0d	-104.000	Central geographic longitude of grid (deg, +east)
wbd	-46.175	Grid's western boundary (rotated degrees)
sbd	-34.540	Grid's southern boundary (rotated degrees)
inpes	10	Number of compute tasks in the I direction
jnpes	5	Number of compute tasks in the J direction
&I/O tasks		
quilting	true	Asynchronous quilting/history writes
write_groups	1	
write_tasks_per_group	1	
&General modes		
global	false	True→ Global; False→ Regional
hydro	false	True→ Hydrostatic; False→ Nonhydrostatic
adiabatic	false	True→ Adiabatic; False→ Diabatic
oper	false	
&Printouts		
print_all	true	Print all statements to err file
print_diag	true	Print diagnostics (CALL FIELD_STATS)
print_esmf	false	Print ESMF return signals
print_output	true	Print info on records written into history/restart
print_timing	true	Print timing info (CPU time)
&Ensemble		
ENS_SPS	false	
RUN_CONTINUE	false	
total_member	1	
PE_MEMBER01	0	

&Dynamics		
secadv	true	True→ 2nd order advection; False→ 4th order
smag2	0.2	Smagorinsky constant for 2nd order diffusion
codamp	9.0	Divergence damping constant
wcor	0.18	Divergence correction factor
idtad	2	Dynamics timestep between calls to the passive advection for dynamics variables
advect_tracers	true	
idtadt	2	Dynamics timestep between calls to the tracer advection (normally 1)
num_tracers_met	4	Number of specified meteorological "tracer" scalars (e.g., water)
num_tracers_chem	0	Number of specified chem/aerosol "tracer" scalars
lnsh	1	Number of boundary blending rows for H points
lnsv	1	Number of boundary blending rows for V points
&Digital Filtering		
filter_method	0	0→ none; 1→ DFL; 2→ DDFI; 3→ TDFI
nsecs_dfl	1800	HALF forward filter window (s) (DFL)
nsecs_bckddfi	1800	HALF backward integration duration (s) (DDFI)
nsecs_fwdddfi	3600	HALF forward filter window (s) (DDFI)
nsecs_bcktdfi	3600	HALF backward filter window (s) (TDFI)
nsecs_fwdtdfi	3600	HALF forward filter window (s) (TDFI)
&Global Summations		
use_allreduce	false	True→ use mpi_allreduce for global sums False→ use mpi send/recv for global sums
read_global_sums	false	Read in global summations
write_global_sums	false	Write out global summations
&Precipitation Assimilation		
pcpflg	false	True→ assimilation on; False→ assimilation off
pcphr	6	
write_prec_adj	true	True→ create baseline prec. file;

		False→ regular run
&Gravity Wave Drag		
gwdflg	false	True→ GWD on; False→ GWD off
cleffamp	1.00	tunable parameter depends on resolution
sigfac	0.00	tunable parameter
factop	0.50	de-acceleration limiter
rlolev	500.00	critical pressure level (check units)
dpmin	5.00	minimum thickness of the reference layer (check units)
&physics		
shortwave longwave	gfdl gfdl	gfdl--> GFDL (shortwave and longwave) gsfc--> Goddard shortwave dudh--> Dudhia shortwave rrtm--> RRTM (shortwave and longwave)
co2tf	1	Controls CO2 input used by the GFDL radiation scheme. 0: Read CO2 functions data from pre- generated file 1: Generate CO2 functions data internally
convection	bmj	bmj --> Betts-Miller-Janjic bmj_dev--> BMJ (development) kf --> Kain-Fritsch sas --> Simplified Arakawa-Schubert gd --> Grell-Devenyi none --> No convection
microphysics	fer	fer--> Ferrier fer_hires--> Ferrier (Eta) thompson --> Thompson (must use 'thompson' and not 'tho') wsm6--> WSM6 gfs--> GFS microphysics
spec_adv	false	Individual cloud species advected
lmprate	false	.true.: 4D array called MPRATES containing 3D microphysics source/sink terms for Fer_hires and wsm6. .false. One 3D array called MPRATES with zero values.
sfc_layer	myj	myj→ Mellor-Yamada-Janjic mm5→ MM5 sfc layer
land_surface	ruc	noah→ NOAH scheme

		liss→ Janjic LSM ruc→ Smirnova LSM
ucmcall	0	Use (1) or do not use (0) the Urban Canopy Model
ivegsrc	0	Vegetation map identifier, 0→ USGS, 1→ IGBP
gfs	false	Select entire GFS physics suite
&Convection Switches		
fres	1.00	resolution factor for dsp's (default)
fr	1.00	land factor for dsp's (default)
fsl	0.85	reduction factor for "slow" dsp's over land (default)
fss	0.85	reduction factor for "slow" dsp's over water (default)
entrain	false	Entrainment
newall	true	New clouds used at all shallow points
newswap	true	New clouds at swap shallow points
newupup	true	New cloud used for both heat and moisture up shallow points
nodeep	false	All deep convection diverted to shallow swap algorithm
&Physics Timesteps		
nrads	17	Number of dynamic timesteps between calls to shortwave
nradl	17	Number of dynamic timesteps between calls to longwave
nphs	2	Number of dynamic timesteps between calls to landsurface and turbulence
nprecip	2	Number of dynamic timesteps between calls to convection and microphysics
nhrs_udef	true	User defined when fluxes are emptied True→ User defiend; False→ Auto NOTE: User must set nhrs_udef to .TRUE. and set the emptying frequencies (nhrs_*) to the desired values or else all accumulations will automatically be emptied hourly.
nhrs_prec	3	Frequency in hours between times when precip arrays are emptied
nhrs_heat	3	Frequency in hours between times when

		heating arrays are emptied
nhrs_clod	3	Frequency in hours between times when cloud arrays are emptied
nhrs_rdlw	3	Frequency in hours between times when LW radiation arrays are emptied
nhrs_rdsw	3	Frequency in hours between times when SW radiation arrays are emptied
nhrs_srfc	3	Frequency in hours between times when sfc evap/flux arrays are emptied
&Write History/Restart Specifications		
nemsio_input	true	
write_hst_bin	true	True→ Write history files in binary format
write_hst_nemsio	true	True→ Write history files in NEMSIO format
write_rst_bin	true	True→ Write restart files in binary format
write_rst_nemsio	true	True→ Write restart files in NEMSIO format
write_nemsioctl	true	True→ Write dtl for nemsio run history files
write_donefileflag	false	
write_fsyncflag	false	True→ write fsync
write_dopost	false	True→ run post on quilt
post_gribversion	"grib1"	grib version for post output
hst_name_base	'nmmb_hst'	
rst_name_base	'nmmb_rst'	
&Nesting		
my_domain_id	1	ID number of this domain (uppermost domain must have ID=1)
my_parent_id	-999	ID number of this domain's parent
n_children	0	Number of child domains for this domain
my_domain_moves	false	Does this domain move?
nest_mode	1-way	1-way or 2-way interaction between parents/children
generation	1	For 2-way only, in which generation is this domain?
num_domains_total	1	Total number of domains in this run (Only needed in domain #1's configuration file)
i_parent_start	127	Nest southwest corner at this parent I
j_parent_start	204	Nest southwest corner at this parent J
parent_child_space_ratio	3	Ratio of parent grid increment to nest's

ratio_sfc_files	0	Ratio of uppermost parent grid increment to this moving nest's
nrows_p_upd_w	2	West boundary rows of moving nest footprint updated by parent
nrows_p_upd_e	2	East boundary rows of moving nest footprint updated by parent
nrows_p_upd_s	2	South boundary rows of moving nest footprint updated by parent
nrows_p_upd_n	2	North boundary rows of moving nest footprint updated by parent
input_ready	false	Nest has pre-generated input file
&Timing		
nhours_clocktime	1	Frequency in hours between clocktime diagnostic prints
npe_print	1	The MPI task that will provide the clocktimes

Setting the Western and Southern Boundaries of the Grid (wbd and sbd in the configure files)

When first creating a domain, one must be able to provide the western and southern boundaries for the configure files (multiple if there are nests) in order to run NMMB. If they are not readily known, it is possible to run nemsinterp.exe using the namelist.nps file to retrieve these values from the domain_details_01 file, which is output by nemsinterp.exe. If there are nests in the domain, multiple domain_details files for these nests will be produced in addition to domain_details_01, and the wbd and sbd values will be listed as wbd(NEST) and sbd(NEST).

It is also possible to obtain the wbd and sbd values from the geogrid standard error file, which is produced when geogrid is run.

How to Run NMMB

Note: For software requirements for running NMMB, how to obtain the NMMB package and how to configure and compile NMMB, see Chapter 2.

Note: Running a real-data case requires first successfully running the NEMS Preprocessing System (NPS) (See Chapter 2 for directions for installing the NPS and Chapter 3 for a description of the NPS and how to run the package).

Running *NEMS.x*

Note: Running ***NEMS.x*** requires a successful run of ***NPS*** as explained in Chapter 3.

- If the working directory used to run ***NEMS.x*** is different than the one used to run ***nemsinterp.exe***, make sure ***configure_file_01,*** as well as the following files are linked in the working directory:

```
> ls
lrwxrwxrwx 1  31 Feb  9 10:34 aerosol.dat ->
      ../../static/TABLES/aerosol.dat
lrwxrwxrwx 1  32 Feb  9 10:34 atm_namelist ->
      ../../static/TABLES/atm_namelist
lrwxrwxrwx 1  28 Feb  9 10:34 atmos.configure ->
      ../../static/atmos.configure
lrwxrwxrwx 1  19 Feb  9 10:34 boco.0000 -> ../npsprd/boco.0000
lrwxrwxrwx 1  19 Feb  9 10:34 boco.0003 -> ../npsprd/boco.0003
lrwxrwxrwx 1  19 Feb  9 10:34 boco.0006 -> ../npsprd/boco.0006
lrwxrwxrwx 1  19 Feb  9 10:34 boco.0009 -> ../npsprd/boco.0009
lrwxrwxrwx 1  19 Feb  9 10:34 boco.0012 -> ../npsprd/boco.0012
lrwxrwxrwx 1  19 Feb  9 10:34 boco.0015 -> ../npsprd/boco.0015
lrwxrwxrwx 1  19 Feb  9 10:34 boco.0018 -> ../npsprd/boco.0018
lrwxrwxrwx 1  19 Feb  9 10:34 boco.0021 -> ../npsprd/boco.0021
lrwxrwxrwx 1  49 Feb  9 10:34 cfs_ice1x1monclim19822001.grb ->
      ../../static/TABLES/cfs_ice1x1monclim19822001.grb
lrwxrwxrwx 1  52 Feb  9 10:34 cfs_oi2sst1x1monclim19822001.grb ->
      ../../static/TABLES/cfs_oi2sst1x1monclim19822001.grb
lrwxrwxrwx 1  46 Feb  9 10:34 co2historicaldata_2008.txt ->
      ../../static/TABLES/co2historicaldata_2008.txt
lrwxrwxrwx 1  46 Feb  9 10:34 co2historicaldata_2009.txt ->
      ../../static/TABLES/co2historicaldata_2009.txt
lrwxrwxrwx 1  46 Feb  9 10:34 co2historicaldata_2010.txt ->
       ../../static/TABLES/co2historicaldata_2010.txt
lrwxrwxrwx 1  46 Feb  9 10:34 co2historicaldata_2011.txt ->
      ../../static/TABLES/co2historicaldata_2011.txt
lrwxrwxrwx 1  46 Feb  9 10:34 co2historicaldata_2012.txt ->
      ../../static/TABLES/co2historicaldata_2012.txt
lrwxrwxrwx 1  46 Feb  9 10:34 co2historicaldata_2013.txt ->
      ../../static/TABLES/co2historicaldata_2013.txt
lrwxrwxrwx 1  46 Feb  9 10:34 co2historicaldata_2014.txt ->
      ../../static/TABLES/co2historicaldata_2014.txt
lrwxrwxrwx 1  46 Feb  9 10:34 co2historicaldata_glob.txt ->
      ../../static/TABLES/co2historicaldata_glob.txt
-rwxr-xr-x 1 15K Feb  9 10:34 configure_file_01
lrwxrwxrwx 1  33 Feb  9 10:34 ETAMPNEW_DATA ->
      ../../static/TABLES/ETAMPNEW_DATA
lrwxrwxrwx 1  47 Feb  9 10:34 ETAMPNEW_DATA.expanded_rain ->
       ../../static/TABLES/ETAMPNEW_DATA.expanded_rain
lrwxrwxrwx 1  52 Feb  9 10:34 ETAMPNEW_DATA.expanded_rain_orig ->
      ../../static/TABLES/ETAMPNEW_DATA.expanded_rain_orig
lrwxrwxrwx 1  27 Feb  9 10:34 fort.28 -> ../../static/TABLES/fort.28
lrwxrwxrwx 1  27 Feb  9 10:34 fort.48 -> ../../static/TABLES/fort.48
lrwxrwxrwx 1  31 Feb  9 10:34 GENPARM.TBL ->
      ../../static/TABLES/GENPARM.TBL
lrwxrwxrwx 1  42 Feb  9 10:34 global_albedo4.1x1.grb ->
```

```
      ../../static/TABLES/global_albedo4.1x1.grb
lrwxrwxrwx 1  49 Feb  9 10:34 global_climaeropac_global.txt ->
      ../../static/TABLES/global_climaeropac_global.txt
lrwxrwxrwx 1  53 Feb  9 10:34 global_co2historicaldata_2004.txt ->
      ../../static/TABLES/global_co2historicaldata_2004.txt
lrwxrwxrwx 1  42 Feb  9 10:34 global_glacier.2x2.grb ->
      ../../static/TABLES/global_glacier.2x2.grb
lrwxrwxrwx 1  41 Feb  9 10:34 global_maxice.2x2.grb ->
      ../../static/TABLES/global_maxice.2x2.grb
lrwxrwxrwx 1  37 Feb  9 10:34 global_o3clim.txt ->
      ../../static/TABLES/global_o3clim.txt
lrwxrwxrwx 1  39 Feb  9 10:34 global_o3prdlos.f77 ->
      ../../static/TABLES/global_o3prdlos.f77
lrwxrwxrwx 1  49 Feb  9 10:34 global_shdmax.0.144x0.144.grb ->
      ../../static/TABLES/global_shdmax.0.144x0.144.grb
lrwxrwxrwx 1  49 Feb  9 10:34 global_shdmin.0.144x0.144.grb ->
      ../../static/TABLES/global_shdmin.0.144x0.144.grb
lrwxrwxrwx 1  40 Feb  9 10:34 global_slope.1x1.grb ->
      ../../static/TABLES/global_slope.1x1.grb
lrwxrwxrwx 1  44 Feb  9 10:34 global_snoclim.1.875.grb ->
      ../../static/TABLES/global_snoclim.1.875.grb
lrwxrwxrwx 1  43 Feb  9 10:34 global_soilmcpc.1x1.grb ->
      ../../static/TABLES/global_soilmcpc.1x1.grb
lrwxrwxrwx 1  43 Feb  9 10:34 global_soiltype.1x1.grb ->
      ../../static/TABLES/global_soiltype.1x1.grb
lrwxrwxrwx 1  46 Feb  9 10:34 global_tg3clim.2.6x1.5.grb ->
      ../../static/TABLES/global_tg3clim.2.6x1.5.grb
lrwxrwxrwx 1  55 Feb  9 10:34 global_vegfrac.0.144.decpercent.grb ->
      ../../static/TABLES/global_vegfrac.0.144.decpercent.grb
lrwxrwxrwx 1  42 Feb  9 10:34 global_vegtype.1x1.grb ->
       ../../static/TABLES/global_vegtype.1x1.grb
lrwxrwxrwx 1  42 Feb  9 10:34 global_zorclim.1x1.grb ->
       ../../static/TABLES/global_zorclim.1x1.grb
lrwxrwxrwx 1  36 Feb  9 10:34 IGBP_LANDUSE.TBL ->
      ../../static/TABLES/IGBP_LANDUSE.TBL
lrwxrwxrwx 1  36 Feb  9 10:34 IGBP_VEGPARM.TBL ->
       ../../static/TABLES/IGBP_VEGPARM.TBL
lrwxrwxrwx 1  25 Feb  9 10:34 input_domain_01 ->
      ../npsprd/input_domain_01
lrwxrwxrwx 1  32 Feb  9 10:34 input_domain_01_nemsio ->
      ../npsprd/input_domain_01_nemsio
lrwxrwxrwx 1  31 Feb  9 10:34 LANDUSE.TBL ->
       ../../static/TABLES/LANDUSE.TBL
lrwxrwxrwx 1  36 Feb  9 10:34 LANDUSE.TBL_igbp ->
      ../../static/TABLES/LANDUSE.TBL_igbp
lrwxrwxrwx 1  17 Feb  9 10:34 model_configure -> configure_file_01
lrwxrwxrwx 1  46 Feb  9 10:34 NEMS.x ->
      /glade/p/ral/jnt/NMMB_Tutorial/NEMS/exe/NEMS.x
lrwxrwxrwx 1  22 Feb  9 10:34 nests.txt -> ../../static/nests.txt
lrwxrwxrwx 1  28 Feb  9 10:34 ocean.configure ->
      ../../static/ocean.configure
lrwxrwxrwx 1  29 Feb  9 10:34 qr_acr_qg ->
../../static/TABLES/qr_acr_qg
```

```
lrwxrwxrwx 1  29 Feb  9 10:34 qr_acr_qs ->
../../static/TABLES/qr_acr_qs
lrwxrwxrwx 1  29 Feb  9 10:34 RRTM_DATA ->
../../static/TABLES/RRTM_DATA
lrwxrwxrwx 1  33 Feb  9 10:34 RRTM_DATA_DBL ->
      ../../static/TABLES/RRTM_DATA_DBL
-rwxr-xr-x 1 713 Feb  9 10:34 run_nems.csh
lrwxrwxrwx 1  38 Feb  9 10:34 seaice_newland.grb ->
      ../../static/TABLES/seaice_newland.grb
lrwxrwxrwx 1  32 Feb  9 10:34 SOILPARM.TBL ->
       ../../static/TABLES/SOILPARM.TBL
lrwxrwxrwx 1  29 Feb  9 10:34 solver_state.txt ->
      ../../static/solver_state.txt
lrwxrwxrwx 1  27 Feb  9 10:34 tr49t67 -> ../../static/TABLES/tr49t67
lrwxrwxrwx 1  27 Feb  9 10:34 tr49t85 -> ../../static/TABLES/tr49t85
lrwxrwxrwx 1  27 Feb  9 10:34 tr67t85 -> ../../static/TABLES/tr67t85
lrwxrwxrwx 1  31 Feb  9 10:34 VEGPARM.TBL ->
       ../../static/TABLES/VEGPARM.TBL
lrwxrwxrwx 1  36 Feb  9 10:34 VEGPARM.TBL_igbp ->
      ../../static/TABLES/VEGPARM.TBL_igbp
```

To run *NEMS.x* a sample script showed below can be used.

```
*******************************************************************
#!/bin/csh -f

# LSF batch script to run the test MPI code
#
#BSUB -a poe                    # at NCAR: bluevista
#BSUB -n 166                    # number of total (MPI) tasks
#BSUB -R "span[ptile=16]"       # run a max of 8 tasks per node
#BSUB -o nems.out               # output filename
#BSUB -e nems.err               # error filename
#BSUB -J nems_nmb               # job name
#BSUB -q premium                # queue
#BSUB -W 1:00                   # wallclock time
#BSUB -P P48503002              # DTC annual account

# Run nems
setenv OMP_NUM_THREADS 1

mpirun.lsf ./NEMS.x

/bin/echo "run_nems.csh completed successfully"
*******************************************************************
```

The submit command is:

```
bsub < run_nems.csh
```

Checking *NEMS.x* output

To confirm whether an NMMB run is successful, look for the text "Successfully completed" at the end of the NEMS log file (e.g., ***nems.out***).

After completing, ***NEMS.x*** will produce output files with the following naming convention:

nmmb_hst_01_nio_00HHh_00m_00.00s.ctl
nmmb_hst_01_nio_00HHh_00m_00.00s

where HH denotes the forecast hour. For example, the first output file for a run started at 0000 UTC, 23rd January 2005 would be:

nmmb_hst_01_nio_0000h_00m_00:00s
The number of ***nmmb_hst*** files generated by a successful run of ***NEMS.x*** will depend on the output options specified in ***configure_file_01*** (i.e**., *minutes_history***).

The nmmb_hst_* files are raw model output files in either nemsio or binary format. These files must be processed through UPP in order to produce output files in GRIB format. However, GrADS can read these raw files directly, as long as an identical *.ctl file is available. Therefore, GrADS can be used to view and plot raw NMMB model fields prior to, or without running UPP. For more information on using GrADS, please see http://iges.org/grads/.

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Chapter 5: NMMB Software

Table of Contents

NMMB Build Mechanism

The NMMB build mechanism provides a uniform apparatus for configuring and compiling the NMMB model and pre-processors over a range of platforms with a variety of options. This section describes the components and functioning of the build mechanism. For information on building the NMMB code, see Chapter 2.

Required software

The NMMB build relies on a number of standard UNIX utilities: perl, csh and Bourne shell, make, M4, sed, awk, and the uname command. The NMMB code itself is mostly standard Fortran. For distributed-memory processing, MPI and related tools and libraries should be installed.

Build Mechanism Components

Directory structure: The directory structure of NMMB consists of the top-level directory plus directories containing files related to the NMMB software framework, the NMMB source (***src)***, executables (***exe)***, necessary utilities (***util***), and scripts (***job***).

Makefiles: The main ***makefile*** (input to the UNIX make utility) is in the ***src*** directory. There are also makefiles in most of the subdirectories that come with NMMB. Make is called recursively over the directory structure.

Configuration files: The ***configure.nems*** file, located in ***src/conf*** contains compiler, linker, and other build settings, as well as rules and macro definitions used by the make utility. The ***configure.nems*** file is included by the Makefiles in most of the NMMB source distribution. The ***configure.nems*** file in the top-level directory is generated each time the configure script is invoked. It is also deleted by ***make clean.*** Thus, ***configure.nems*** is the place to make temporary changes, such as optimization levels and compiling with debugging.

Environment variables: Certain aspects of the configuration and build are controlled by environment variables: the non-standard locations of NetCDF libraries or the Perl command, machine-specific features, and optional build libraries (e.g. Grib Edition 2,).

In addition to NMMB-related environment settings, there may also be settings specific to particular compilers or libraries. For example, local installations may require setting a variable like ***MPICH_F90*** to make sure the correct instance of the Fortran compiler is used by the ***mpif90*** command. These settings may be specified in the ***configure.nems*** file.

How the NMMB build works

There are two steps in building NMMB: configuration and compilation.

Configuration: The ***configure*** script configures the model for compilation on your system by copying appropriate configuration file. The ***configure*** script, if invoked by itself, will list available compiler options to the user as follows:

Run ./configure with one argument:

'configure 3_wcoss' : ESMF 3.1.0rp2 library on wcoss
'configure 3_gaea' : ESMF 3.1.0r series library on zeus

'configure 3_yellowstone' : ESMF 3.1.0rp2 library on yellowstone
'configure 6.3r_nmm_wcoss' : ESMF 6.3.0r library on wcoss for nmm
'configure 6.3r_gsm_wcoss' : ESMF 6.3.0r library on wcoss for gsm
'configure 6.3r_nmm_theia' : ESMF 6.3.0r library on theia for nmm
'configure 6.3r_gsm_theia' : ESMF 6.3.0r library on theia for gsm

'configure 6_yellowstone' : ESMF 6.3.0r series library on yellowstone

'configure nuopc_wcoss' : ESMF lib with reference NUOPC Layer on wcoss
'configure nuopc_gaea' : ESMF lib with reference NUOPC Layer on gaea

The selected system compile option then must follow ***configure*** on the command line as shown above (e.g., '***configure 6_yellowstone***') to create the ***configure.nems*** file in the ***src/conf*** directory. This file may be edited but changes are temporary since the file will be deleted by ***make clean*** or overwritten by the next invocation of the ***configure*** script. Note that not only is the user specifying the machine by this selection, but also the preferred version of the ESMF library.

Compilation: Running "***make nmm***" in the ***src*** directory compiles the NMMB code after it has been configured using the ***configure*** script. The ***makefile*** in the ***src*** directory directs the rest of the build, accomplished as a set of recursive invocations of make in the subdirectories of NMMB. Most of these makefiles include the ***configure.nems*** file from the ***src*** directory.

Source files (.F and, in some of the external directories, .F90) are preprocessed to produce .f90 files, which are input to the compiler. Compiling the .f90 files results in the creation of object (***.o***) files. The linking step produces the ***NEMS.x*** executable in the ***exe*** directory. Users interested in making changes to the NMMB source code should modify the files with .F and .F90 suffixes, and not their lower case counterparts.

The .o files and .f90 files from a compile are retained until the next invocation of the ***clean*** script. The .f90 files provide the true reference for tracking down run time errors that refer to line numbers or for sessions using interactive debugging tools such as dbx or gdb.

Solver State File

The solver state file provides a high-level single-point-of-control over the fundamental structure of the model data, and thus provides considerable utility for developers and maintainers. It contains lists describing state data fields and their attributes: dimensionality, association with NMMB I/O streams, communication operations, and run time configuration options. The solver state file is located in the ***static*** directory.

Every variable that is an input or an output field is described in the solver state file. Additionally, every variable that is required for parallel communication, specifically associated with a physics package is contained in the solver state file. For each of these variables, associated IO, restart and requirements are defined. For most users, to add a variable into the model would require:

- Declare the variable in the SOLVER_INTERNAL_STATE
- Add a call to SET_VAR_PTR subroutine in SOLVER_INTERNAL_STATE to allocate the memory
- Add a line containing the variable name to the solver_state.txt file.

Solver State File Syntax

Each entry in the solver state file is for a specific variable. When adding to the solver state file, most users find that it is helpful to copy an entry that is similar to the anticipated new entry, and then modify that solver state file entry. White space separates identifiers in each entry. Variables in the file are separated into categories based on their dimension (0D to 4D) and precision (real or integer).

Note: Do not simply remove an identifier and leave a supposed token blank, use the appropriate default value (currently a dash character “-“).

Solver State File Entries

The NMMB solver state file has the following types of entries:

Name – Name of the state or local variable as defined in NMMB code
History – Defines whether a variable will be written to output files
Restart – Specifies whether a variable will be included in restart files
Owned – Specifies whether to allocate memory for variable storage
Import – Depreciated (to be removed in a future release)
eXport – Depreciated (to be removed in a future release)
Time_ser – Defines whether a variable will be included in time series files
Description – Full description of the variable defined in ***Name***

These ***keywords*** appear at the top of the solver state file to define which type of information is being provided within a specific column of the file.

Solver State File - Name

The ***name*** keyword refers to the specific variable name as defined in the NMMB model code. Single quotes are used to delineate this attribute. When adding new variables to the solver state file, users are warned to make sure that variable names are unique.

Solver State File - History

An ***H*** under this column indicates that a specific variable will be written to output files. If a variable is not desired, a dash character should replace the ***H***.

Solver State File - Restart

An ***R*** under this column tells the NMMB code to include a specific variable in restart files needed to restart an NMMB run. When a certain variable is not desired within restart files, a dash character should replace the ***R***.

Solver State File - Owned

An ***O*** under this column defines whether a variable should have memory allocated for its storage. Typically all variables should have this flag, unless they are simple "tracer" variables.

Solver State File - Import/eXport

Legacy flags from an earlier version of the solver state file. These flags can be ignored and will be removed in a future release of NMMB.

Solver State File - Time_ser

A ***T*** under this column will include a given variable in time series output files.

Solver State File - Description
The last column in the solver state file contains a description of each variable in single quotes. Some variables also contain comments below this entry detailing information related to the variable description.

Important Note When Running Nests in NMMB

The nests.txt file must also be included in the working directory of NMMB runs when running nests, however its contents are ignored if there are none. As in the solver_state.txt file, all the variables listed in the nests.txt file are from the solver component's internal state. Three columns allow the user to specify which variables: (1) are part of: the nest boundary updates; (2) are updated by the parent in those regions of moving nest domains that shift outside of their pre-move footprint; (3) are updated in the parent by the nests in upscale 2-way exchange.

Chapter 6: Post Processing

Table of Contents

NCEP Unified Post Processor (UPP)

UPP Introduction

The UPP software package is based on the WRF Post Processor (WPP) but has enhanced capabilities to post-process output from a variety of NWP models, including WRF-NMM, WRF-ARW, Non-hydrostatic Multi-scale Model on the B grid (NMMB), Global Forecast System (GFS), and Climate Forecast System (CFS). UPP interpolates output from the model's native grids to National Weather Service (NWS) standard levels (pressure, height, etc.) and standard output grids (AWIPS, Lambert Conformal, polar-stereographic, etc.) in NWS and World Meteorological Organization (WMO) GRIB format. There is also an option to output fields on the model's native vertical levels. Preliminary code has now been introduced to output in GRIB Edition 2 (GRIB2) format as well. In addition, UPP incorporates the Joint Center for Satellite Data Assimilation (JCSDA) Community Radiative Transfer Model (CRTM) to compute model derived brightness temperature (T_B) for various instruments and channels. This additional feature enables the generation of simulated GOES and AMSRE products for a variety of models.

UPP Software Requirements

The Community Unified Post Processor requires the same Fortran and C compilers used to build the NMMB model. In addition, the netCDF library, the JasPer library, the PNG library, Zlib, and the NMMB I/O API libraries are also required. NCEP provides these necessary codes for download: http://www.nco.ncep.noaa.gov/pmb/codes/GRIB2/

The Unified Post Processor has been tested on IBM (with XLF compiler) and LINUX platforms (with PGI, Intel and GFORTRAN compilers).

Obtaining the UPP Code

The Unified Post Processor package can be downloaded from: http://www.dtcenter.org/wrf-nmm/users/downloads/.

Note: Always obtain the latest version of the code if you are not trying to continue a pre-existing project. UPPV2.2 is just used as an example here.

Once the ***tar*** file is obtained, ***gunzip*** and ***untar*** the file.

tar –zxvf UPPV2.2.tar.gz

This command will create a directory called ***UPPV2.2***.

UPP Directory Structure

Under the main directory of ***UPPV2.2*** reside seven subdirectories (* indicates directories that are created after the configuration step):

arch: Machine dependent configuration build scripts used to construct ***configure.upp***

bin*: Location of executables after compilation.

scripts: contains sample running scripts
- **run_unipost**: run ***unipost***, ***ndate*** and ***copygb***.
- **run_unipost andgempak**: run ***unipost***, ***copygb***, and GEMPAK to plot various fields.
- **run_unipost andgrads**: run ***unipost***, ***ndate***, ***copygb***, and GrADS to plot various fields.
- **run_unipost _frames**: run ***unipost***, ***ndate*** and ***copygb*** on a single ***NMMB*** output file containing multiple forecast times.
- **run_unipost _gracet**: run ***unipost***, ***ndate*** and ***copygb*** on ***NMMB*** output files with non-zero minutes/seconds.
- **run_unipost _minute**: run ***unipost***, ***ndate*** and ***copygb*** for sub-hourly ***NMMB*** output files.

include*: Source include modules built/used during compilation of UPP

lib*: Archived libraries built/used by UPP

parm: Contains the parameter files, which can be modified by the user to control how the post processing is performed.

src: Contains source codes for:
- **copygb:** Source code for ***copygb***
- **ndate:** Source code for ***ndate***
- **unipost:** Source code for ***unipost***
- **lib**: Contains source code subdirectories for the UPP libraries
  - **bacio**: Binary I/O library
  - **crtm2**: Community Radiative Transfer Model library
  - **g2:** GRIB2 support library
  - **g2tmpl:** GRIB2 table support library
  - **gfsio:** GFS I/O routines
  - **ip**: General interpolation library (see ***lib/ip/iplib.doc***)
  - **nemsio**: NEMS I/O routines
  - **sfcio**: API for performing I/O on the surface restart file of the global spectral model
  - **sigio**: API for performing I/O on the sigma restart file of the global spectral model
  - **sp**: Spectral transform library (see ***lib/sp/splib.doc***)
  - **w3emc**: Library for coding and decoding data in GRIB1 format
  - **w3nco**: Library for coding and decoding data in GRIB1 format
  - **wrfmpi_stubs**: Contains some ***C*** and ***FORTRAN*** codes to generate ***libmpi.a*** library used to replace MPI calls for serial compilation.
  - **xml**: XML support – GRIB2 parameter file

Installing the UPP Code

There are two environment variables which must be set before beginning the installation: a variable to define the path to a similarly compiled version of WRF-ARW and a variable to a compatible version of netCDF. If the environment variable ***WRF_DIR*** is set by (for example),

setenv WRF_DIR */home/user/WRFV3*

this path will be used to reference WRF-ARW libraries and modules, as UPP relies on WRF-ARW i/o routines. Otherwise, the path

../WRFV3

will be used.

In the case neither method is set, the configure script will automatically prompt you for a pathname.

To reference the netCDF libraries, the configure script checks for an environment variable (***NETCDF***) first, then the system default (***/user/local/netcdf***), and then a user supplied link (***./netcdf_links***). If none of these resolve a path, the user will be prompted by the configure script to supply a path.

Type ***configure***, and provide the required info. For example:

./configure

You will be given a list of choices for your computer.

<u>Choices for LINUX operating systems are as follows:</u>

1. Linux x86_64, PGI compiler (serial)
2. Linux x86_64, PGI compiler (dmpar)
3. Linux x86_64, Intel compiler (serial)
4. Linux x86_64, Intel compiler (dmpar)
5. Linux x86_64, Intel compiler, SGI MPT (serial)
6. Linux x86_64, Intel compiler, SGI MPT (dmpar)
7. Linux x86_64, gfortran compiler (serial)
8. Linux x86_64, gfortran compiler (dmpar)

Note*: If UPP is compiled with distributed memory, it must be linked to a dmpar compilation of WRF-ARW.*

Choose one of the configure options listed. Check the ***configure.upp*** file created and edit for compile options/paths, if necessary. For debug flag settings, the configure script can be run with a ***–d*** switch or flag.

To compile UPP, enter the following command:

./compile >& compile_upp.log &

When compiling with distributed memory (serial) this command should create 13 (14) UPP libraries in ***UPPV2.2/lib/*** (***libbacio.a***, ***libCRTM.a***, ***libg2.a***, ***libg2tmpl.a***, ***libgfsio.a***, ***libip.a***, ***(libmpi.a)***, ***libnemsio.a***, ***ibsfcio.a***, ***libsigio.a***, ***libsp.a***, ***libw3emc.a, libw3nco.a , libxmlparse.a***) and three UPP executables in ***bin/*** (***unipost.exe***, ***ndate.exe***, and ***copygb.exe***).

To remove all built files, as well as the ***configure.upp***, type:

./clean

This action is recommended if a mistake is made during the installation process or a change is made to the configuration or build environment. There is also a ***clean –a*** option which will revert back to a pre-install configuration.

UPP Functionalities

The Unified Post Processor,

- is compatible with WRF version 3.5 and above
- can be used to post-process WRF-ARW, WRF-NMM, NMMB, GFS, and CFS forecasts (community support provided for WRF and NMMB-based forecasts).
- can ingest NMMB history files (***nmmb_hst****) in binary.

The Unified Post Processor is divided into two parts:

- ***Unipost***
  - Interpolates the forecasts from the model's native vertical coordinate to NWS standard output levels (e.g., pressure, height) and computes mean sea level pressure. If the requested parameter is on a model's native level, then no vertical interpolation is performed.
  - Computes diagnostic output quantities (e.g., convective available potential energy, helicity, radar reflectivity). A full list of fields that can be generated by ***unipost*** is shown in Table 1.
  - Outputs the results in NWS and WMO standard GRIB1 or GRIB2 format
  - Outputs navigation file ***copygb_gridnav.txt***. This file can be used as input for ***copygb***.
- ***copygb_gridnav.txt:***
  - contains the GRID GDS of a Lambert Conformal Grid similar in domain and grid spacing to the one used to run the NMMB. The Lambert Conformal map projection works well for mid-latitudes.
- ***Copygb***
  - Destaggers the NMMB forecasts from the staggered native B-grid to a regular non-staggered grid.
  - Interpolates the forecasts horizontally from their native grid to a standard AWIPS or user-defined grid
  - Outputs the results in NWS and WMO standard GRIB1 format

In addition to ***unipost*** and ***copygb***, a utility called ***ndate*** is distributed with the Unified Post Processor tarfile. This utility is used to format the dates of the forecasts to be posted for ingestion by the code.

Setting up the NMMB model to interface with UPP

The ***unipost*** program is currently set up to read a large number of fields from the NMMB model history files. Unipost is configured such that it will run successfully even if an expected input field is missing from the NMMB history file as long as this field is not required to produce a requested output field. If the pre-requisites for a requested output field are missing from the NMMB history file, ***unipost*** will abort at run time.

Take care not to remove fields from the ***nmb*** output files, which may be needed for diagnostic purposes by the UPP package. In general, the default fields available in the ***nmb*** output files are sufficient to run UPP. The fields written to the NMMB history file are controlled by the settings in the solver state file (see solver_state.txt), and ***unipost*** is capable of reading all fields found in this file.

UPP Control File Overview

The user interacts with ***unipost*** through the control file, ***parm/wrf_cntrl.parm*** (for NMMB, this file should be renamed ***nmb_cntrl.parm***, and will be referred to as such hereafter). The control file is composed of a header and a body. The header specifies the output file information. The body allows the user to select which fields and levels to process.

The header of the ***nmb_cntrl.parm*** file contains the following variables:

- **KGTYPE**: defines output grid type, which should always be 255.
- **IMDLTY:** identifies the process ID for AWIPS.
- **DATSET**: defines the prefix used for the output file name. Currently set to "***wrfprs***". Note: the run_* scripts assume "***wrfprs***" is used. This should be changed to "***nmbprs***, ***nmbnat***, or ***nmbtwo***" for NMMB.

The body of the ***nmb_cntrl.parm*** file is composed of a series of line pairs similar to the following:

```
(PRESS ON MDL SFCS   ) SCAL=( 3.0)
L=(11000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000
00000 00000 00000)
```

where,

- The top line specifies the variable (e.g. PRESS) to process, the level type (e.g. ON MDL SFCS) a user is interested in, and the degree of accuracy to be retained (SCAL=3.0) in the GRIB output.
  - SCAL defines the precision of the data written out to the GRIB format. Positive values denote decimal scaling (maintain that number of significant digits), while negative values describe binary scaling (precise to 2^{SCAL}; i.e., SCAL=-3.0 gives output precise to the nearest 1/8). Because ***copygb*** is unable to handle binary precision at this time, negative numbers are discouraged.
  - A list of all possible output fields for ***unipost*** is provided in Table 1. This

table provides the full name of the variable in the first column and an abbreviated name in the second column. The abbreviated names are used in the control file. Note that the variable names also contain the type of level on which they are output. For instance, temperature is available on "model surface" and "pressure surface".

- The second line specifies the levels on which the variable is to be posted. "0" indicates no output at this level and "1" indicates output the variable specified on the top line at the level specified by the position of the digit and the type of level defined for this variable. For flight/wind energy fields, a "2" may be specified, such that "2" requests AGL and "1" requests MSL.

Controlling which variables *unipost* outputs

To output a field, the body of the control file needs to contain an entry for the appropriate variable and output for this variable must be turned on for at least one level (see "*Controlling which levels unipost outputs*"). If an entry for a particular field is not yet available in the control file, two lines may be added to the control file with the appropriate entries for that field.

Controlling which levels *unipost* outputs

The second line of each pair determines which levels ***unipost*** will output. Output on a given level is turned off by a "0" or turned on by a "1".

- For isobaric output, 47 levels are possible, from 2 to 1013 hPa (*2, 5, 7, 10, 20, 30, 50, 70 mb and then every 25 mb from 75 to 1000 mb*). The complete list of levels is specified in ***src/unipost/CTLBLK.f***.
    - o Modify specification of variable LSMDEF to change the number of pressure levels: LSMDEF=47
    - o Modify specification of SPLDEF array to change the values of pressure levels:

    (/200.,500.,700.,1000.,2000.,3000.
    &,5000.,7000.,7500.,10000.,12500.,15000.,17500.,20000., …/)
- For model-level output, all model levels are possible, from the highest to the lowest.
- When using the Noah LSM, the *soil layers* are 0-10 cm, 10-40 cm, 40-100 cm, and 100-200 cm.
- When using the RUC LSM, the *soil levels* are 0 cm, 5 cm, 20 cm, 40 cm, 160 cm, and 300 cm. For the RUC LSM it is also necessary to turn on two additional output levels in the ***nmb_cntrl.parm*** to output 6 levels rather than the default 4 layers for the Noah LSM.
- For PBL layer averages, the levels correspond to 6 layers with a thickness of 30 hPa each.
- For flight level, the levels are 30 m, 50 m, 80 m, 100 m, 305 m, 457 m, 610 m, 914 m,1524 m,1829 m, 2134 m, 2743 m, 3658 m, 4572 m, and 6000 m.

- For AGL RADAR Reflectivity, the levels are 4000 and 1000 m.
- For surface or shelter-level output, only the first position of the line needs to be turned on.
    - For example, the sample control file parm/nmb_cntrl.parm has the following entry for surface dew point temperature:

      (SURFACE DEWPOINT   ) SCAL=(4.0)
      L=(00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000)

      Based on this entry, surface dew point temperature will not be output by ***unipost***. To add this field to the output, modify the entry to read:

      (SURFACE DEWPOINT   ) SCAL=(4.0)
      L=(10000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000)

Running UPP

Six scripts for running the Unified Post Processor package are included in the tar file:

run_unipost
run_unipostandgrads
run_unipostandgempak
run_unipost_frames
run_unipost_gracet
run_unipost_minute

Before running any of the above listed scripts, perform the following instructions:

1. ***cd*** to your ***DOMAINPATH*** directory.

2. Make a directory to put the UPP results.

    mkdir nemsprd

3. Make a directory to put a copy of the ***nmb_cntrl.parm*** file inside.

    mkdir parm

4. Copy over the default ***UPPV2.2/parm/nmb_cntrl.parm*** to your working directory to customize ***unipost***.

5. Edit the ***nmb_cntrl.parm*** file to reflect the fields and levels you want ***unipost*** to output.

6. Copy over the (***UPPV2.2/scripts/run_unipost****) script of your choice to the ***postprd/***.

7. Edit the run script as outlined below, as well as to replace file and path references to WRF-ARW with NMMB.

Once these directories are set up and the edits outlined above are completed, the scripts can be run interactively from the ***postprd*** directory by simply typing the script name on the command line.

Overview of the scripts to run the UPP

Note: It is recommended that the user refer to the ***run_unipost**** scripts in the ***script/*** while reading this overview.

- Set up variables:
  TOP_DIR: top level directory for source codes (***UPPV2.2*** and ***WRFV3***)
  DOMAINPATH: directory where UPP will be run from
  WRFPATH: path to your WRFV3 build; defaults to the environment variable used during the installation with the configure script
  UNI_POST_HOME: path to your UPPV2.2 build
  POSTEXEC: path to your UPPV2.2 executables

  Note: The scripts are configured such that ***unipost*** expects the NMMB history files (***NMB*** output files) to be in ***nemsprd/***, the ***nmb_cntrl.parm*** file to be in ***parm/*** and the postprocessor working directory to called ***postprd/***, all under ***DOMAINPATH***.

- Specify dynamic core being run: NMM (when using WRF-NMM and NMMB)

- Specify the forecast cycles to be post-processed
  startdate: YYYYMMDDHH of forecast cycle
  fhr: first forecast hour
  lastfhr: last forecast hour
  incrementhr: increment (in hours) between forecast files (Do not set to 0 or the script will loop continuously)

- Set naming convention for prefix and extension of output file name
  - ***comsp*** is the initial string of the output file name (by default it is not set (and the prefix of the output file will be the string set in ***nmb_cntrl.parm*** **DATSET**), if set it will concatenate the setting to the front of the string specified in ***nmb_cntrl.parm*** **DATSET**)
  - ***tmmark*** is used for the file extension (in ***run_unipost***, *tmmark=tm00*, if not set it is set to *.GrbF*)

- Set up how many domains will be post-processed
  For runs with a single domain, use "for domain d01".
  For runs with multiple domains, use "for domain d01 d02 .. d*nn*"

- Create namelist ***itag*** that will be read in by ***unipost.exe*** from stdin (unit 5). This namelist contains 5 lines:
  - Name of the NMMB output file to be posted.
  - Format of NMMB model output: **binarympiio**.
  - Format of UPP output (grib1 or grib2)
  - Forecast valid time (not model start time) in NMMB format (the forecast time desired to be post-processed).
  - Dynamic core used: **NMM** (Used for both WRF-NMM and NMMB).

  Note: With the addition of GRIB2 output capabilities, a fifth line has been added to the namelist. If the third line (i.e., UPP output type) is not set, UPP will default the output file format to "grib1".

- Run ***unipost*** and check for errors.
  - The execution command in the distributed scripts is for a single processor: *./**unipost.exe > outpost 2>&1***.
  - To run ***unipost*** using mpi (dmpar compilation), the command line should be:
  - LINUX-MPI systems: ***mpirun -np N unipost.exe > outpost 2>&1*** (Note: on some systems a host file also needs to be specified: ***–machinefile*** "***host***")
  - IBM: ***mpirun.lsf unipost.exe < itag > outpost***

- Set up grid to post to (see full description under "Run ***copygb***" below)
  copygb is run with a pre-defined AWIPS grid
  gridno: standard AWIPS grid to interpolate NMMB model output to
  copygb ingests a kgds definition on the command line
  copygb ingests the contents of file ***copygb_gridnav.txt*** through variable ***nav***

- Run ***copygb*** and check for errors.
  copygb.exe –xg"grid [kgds]" input_file output_file
  where ***grid*** refers to the output grid to which the native forecast is being interpolated.

  The output grid can be specified in three ways:

  i. As the grid id of a pre-defined AWIPS grid:

  copygb.exe -g${gridno} -x input_file output_file

  For example, using grid 218:

copygb.exe -xg“218” nmbprs_$domain.${fhr} nmbprs_$domain .${fhr}

ii. As a user defined standard grid, such as for grid 255:

copygb.exe –xg“255 kgds” input_file output_file

where the user defined grid is specified by a full set of kgds parameters determining a GRIB GDS (grid description section) in the ***W3fi63*** format. Details on how to specify the kgds parameters are documented in file ***lib/w3lib/w3fi71.f***. For example:

copygb.exe -xg“ 255 3 109 91 37719 -77645 8 -71000 10433 9966 0 64 42000 42000” nmbprs_$domain.${fhr} nmbprs_$domain.${fhr}

iii. Specifying output grid as a file: When NMMB output is processed by ***unipost***, ***copygb_gridnav.txt*** is created. This file contain the GRID GDS of a Lambert Conformal Grid (file ***copygb_gridnav.txt***) similar in domain and grid spacing to the one used to run the NMMB model. The contents of this file is read into variable ***nav*** and can be used as input to ***copygb.exe***.

copygb.exe -xg“$nav” input_file output_file

For example, when using “***copygb_gridnav.txt”*** for an application, the steps include:

read nav < 'copygb_gridnav.txt'
export nav
copygb.exe -xg"${nav}" nmbprs_$domain.${fhr} nmbprs_$domain.${fhr}

If scripts ***run_unipostandgrads*** or ***run_unipostandgempak*** are used, additional steps are taken to create image files (see **Visualization** section below).

Upon a successful run, ***unipost*** and ***copygb*** will generate output files ***nmbprs_d****nn***.***hh*** and ***nmbprs_d****nn.hh*, respectively, in the post-processor working directory, where “*nn”* refers to the domain id and “*hh”* denotes the forecast hour. If the run did not complete successfully, a log file in the post-processor working directory called ***unipost_dnn.hh.out***, where “*nn”* is the domain id and “*hh”* is the forecast hour, may be consulted for further information.

Visualization with UPP

GEMPAK

The GEMPAK utility ***nagrib*** is able to decode GRIB files whose navigation is on any non-staggered grid. Hence, GEMPAK is able to decode GRIB files generated by the Unified Post Processing package and plot horizontal fields or vertical cross sections.

A sample script named ***run_unipostandgempak***, which is included in the ***scripts*** directory of the tar file, can be used to run ***unipost***, ***copygb***, and plot the following fields using GEMPAK:

- ***Sfcmap_dnn_hh.gif:*** mean SLP and 6 hourly precipitation
- ***PrecipType_dnn_hh.gif:*** precipitation type (just snow and rain)
- ***850mbRH_dnn_hh.gif:*** 850 mb relative humidity
- ***850mbTempandWind_dnn_hh.gif:*** 850 mb temperature and wind vectors
- ***500mbHandVort_dnn_hh.gif:*** 500 mb geopotential height and vorticity
- ***250mbWindandH_dnn_hh.gif:*** 250 mb wind speed isotacs and geopotential height

This script can be modified to customize fields for output. GEMPAK has an online users guide at
http://www.unidata.ucar.edu/software/gempak/help_and_documentation/manual/.

In order to use the script ***run_unipostandgempak***, it is necessary to set the environment variable ***GEMEXEC*** to the path of the GEMPAK executables. For example,

setenv GEMEXEC /usr/local/gempak/bin

Note: For GEMPAK, the precipitation accumulation period for NMMB is given by the variable ***incrementhr*** in the ***run_unipostandgempak*** script.

GrADS

The GrADS utilities ***grib2ctl.pl*** and ***gribmap*** are able to decode GRIB files whose navigation is on any non-staggered grid. These utilities and instructions on how to use them to generate GrADS control files are available from:
http://www.cpc.ncep.noaa.gov/products/wesley/grib2ctl.html.

The GrADS package is available from: http://grads.iges.org/grads/grads.html.
GrADS has an online User's Guide at: http://grads.iges.org/grads/gadoc/ and a list of basic commands for GrADS can be found at:
http://grads.iges.org/grads/gadoc/reference_card.pdf.

A sample script named ***run_unipostandgrads***, which is included in the ***scripts*** directory of the Unified Post Processing package, can be used to run ***unipost***, ***copygb***, and plot the following fields using GrADS:

- ***Sfcmaphh_dnn_GRADS.gif***: mean SLP and 6-hour accumulated precipitation.

- ***850mbRHhh_dnn_GRADS.gif***: 850 mb relative humidity
- ***850mbTempandWindhh_dnn_GRADS.gif***: 850 mb temperature and wind vectors
- ***500mbHandVorthh_dnn_GRADS.gif***: 500 mb geopotential heights and absolute vorticity
- ***250mbWindandHhh_dnn_GRADS.gif***: 250 mb wind speed isotacs and geopotential heights

In order to use the script ***run_unipostandgrads***, it is necessary to:

1. Set the environmental variable ***GADDIR*** to the path of the GrADS fonts and auxiliary files. For example,

   setenv GADDIR /usr/local/grads/data

1. Add the location of the GrADS executables to the ***PATH***. For example

   setenv PATH /usr/local/grads/bin:$PATH

1. Link script ***cbar.gs*** to the post-processor working directory. (This scripts is provided in UPP package, and the ***run_unipostandgrads*** script makes a link from ***scripts/*** to ***postprd/***.) To generate the plots above, GrADS script ***cbar.gs*** is invoked. This script can also be obtained from the GrADS library of scripts at http://grads.iges.org/grads/gadoc/library.html.

Note: For GrADS, the precipitation accumulation period for WRF-NMM is plotted over the subintervals of the ***tprec*** hour (set in ***namelist.input***).

List of example fields produced by *unipost*

Table 1 lists a number of example basic and derived fields that can be produced by ***unipost***. The abbreviated names listed in the second column describe how the fields should be entered in the control file (***nmb_cntrl.parm***).

Table 1: *List of example fields which can be produced by **unipost** (column 1). Abbreviated names used in the **nmb_cntrl.parm** file (column 2), corresponding GRIB identification number for the field (column 3), and corresponding GRIB identification number for the vertical coordinate (column 4) are shown.*

Field Name	Name In Control File	Grib ID	Vertical Level
Radar reflectivity on model surface	RADAR REFL MDL SFCS	211	109
Pressure on model surface	PRESS ON MDL SFCS	1	109

Height on model surface	HEIGHT ON MDL SFCS	7	109
Temperature on model surface	TEMP ON MDL SFCS	11	109
Potential temperature on model surface	POT TEMP ON MDL SFCS	13	109
Dew point temperature on model surface	DWPT TEMP ON MDL SFC	17	109
Specific humidity on model surface	SPEC HUM ON MDL SFCS	51	109
Relative humidity on model surface	REL HUM ON MDL SFCS	52	109
Moisture convergence on model surface	MST CNVG ON MDL SFCS	135	109
U component wind on model surface	U WIND ON MDL SFCS	33	109
V component wind on model surface	V WIND ON MDL SFCS	34	109
Cloud water on model surface	CLD WTR ON MDL SFCS	153	109
Cloud ice on model surface	CLD ICE ON MDL SFCS	58	109
Rain on model surface	RAIN ON MDL SFCS	170	109
Snow on model surface	SNOW ON MDL SFCS	171	109
Cloud fraction on model surface	CLD FRAC ON MDL SFCS	71	109
Omega on model surface	OMEGA ON MDL SFCS	39	109
Absolute vorticity on model surface	ABS VORT ON MDL SFCS	41	109
Geostrophic streamfunction on model surface	STRMFUNC ON MDL SFCS	35	109
Turbulent kinetic energy on model surface	TRBLNT KE ON MDL SFC	158	109
Richardson number on model surface	RCHDSN NO ON MDL SFC	254	109
Master length scale on model surface	MASTER LENGTH SCALE	226	109
Asymptotic length scale on model surface	ASYMPT MSTR LEN SCL	227	109
Radar reflectivity on pressure surface	RADAR REFL ON P SFCS	211	100
Height on pressure surface	HEIGHT OF PRESS SFCS	7	100
Temperature on pressure surface	TEMP ON PRESS SFCS	11	100
Potential temperature on pressure surface	POT TEMP ON P SFCS	13	100
Dew point temperature on	DWPT TEMP ON P SFCS	17	100

pressure surface			
Specific humidity on pressure surface	SPEC HUM ON P SFCS	51	100
Relative humidity on pressure surface	REL HUMID ON P SFCS	52	100
Moisture convergence on pressure surface	MST CNVG ON P SFCS	135	100
U component wind on pressure surface	U WIND ON PRESS SFCS	33	100
V component wind on pressure surface	V WIND ON PRESS SFCS	34	100
Omega on pressure surface	OMEGA ON PRESS SFCS	39	100
Absolute vorticity on pressure surface	ABS VORT ON P SFCS	41	100
Geostrophic streamfunction on pressure surface	STRMFUNC ON P SFCS	35	100
Turbulent kinetic energy on pressure surface	TRBLNT KE ON P SFCS	158	100
Cloud water on pressure surface	CLOUD WATR ON P SFCS	153	100
Cloud ice on pressure surface	CLOUD ICE ON P SFCS	58	100
Rain on pressure surface	RAIN ON P SFCS	170	100
Snow water on pressure surface	SNOW ON P SFCS	171	100
Total condensate on pressure surface	CONDENSATE ON P SFCS	135	100
Mesinger (Membrane) sea level pressure	MESINGER MEAN SLP	130	102
Shuell sea level pressure	SHUELL MEAN SLP	2	102
2 M pressure	SHELTER PRESSURE	1	105
2 M temperature	SHELTER TEMPERATURE	11	105
2 M specific humidity	SHELTER SPEC HUMID	51	105
2 M mixing ratio	SHELTER MIX RATIO	53	105
2 M dew point temperature	SHELTER DEWPOINT	17	105
2 M RH	SHELTER REL HUMID	52	105
10 M u component wind	U WIND AT ANEMOM HT	33	105
10 M v component wind	V WIND AT ANEMOM HT	34	105
10 M potential temperature	POT TEMP AT 10 M	13	105
10 M specific humidity	SPEC HUM AT 10 M	51	105
Surface pressure	SURFACE PRESSURE	1	1
Terrain height	SURFACE HEIGHT	7	1
Skin potential temperature	SURFACE POT TEMP	13	1

Skin specific humidity	SURFACE SPEC HUMID	51	1
Skin dew point temperature	SURFACE DEWPOINT	17	1
Skin Relative humidity	SURFACE REL HUMID	52	1
Skin temperature	SFC (SKIN) TEMPRATUR	11	1
Soil temperature at the bottom of soil layers	BOTTOM SOIL TEMP	85	111
Soil temperature in between each of soil layers	SOIL TEMPERATURE	85	112
Soil moisture in between each of soil layers	SOIL MOISTURE	144	112
Snow water equivalent	SNOW WATER EQUIVALNT	65	1
Snow cover in percentage	PERCENT SNOW COVER	238	1
Heat exchange coeff at surface	SFC EXCHANGE COEF	208	1
Vegetation cover	GREEN VEG COVER	87	1
Soil moisture availability	SOIL MOISTURE AVAIL	207	112
Ground heat flux - instantaneous	INST GROUND HEAT FLX	155	1
Lifted index—surface based	LIFTED INDEX—SURFCE	131	101
Lifted index—best	LIFTED INDEX—BEST	132	116
Lifted index—from boundary layer	LIFTED INDEX—BNDLYR	24	116
CAPE	CNVCT AVBL POT ENRGY	157	1
CIN	CNVCT INHIBITION	156	1
Column integrated precipitable water	PRECIPITABLE WATER	54	200
Column integrated cloud water	TOTAL COLUMN CLD WTR	136	200
Column integrated cloud ice	TOTAL COLUMN CLD ICE	137	200
Column integrated rain	TOTAL COLUMN RAIN	138	200
Column integrated snow	TOTAL COLUMN SNOW	139	200
Column integrated total condensate	TOTAL COL CONDENSATE	140	200
Helicity	STORM REL HELICITY	190	106
U component storm motion	U COMP STORM MOTION	196	106
V component storm motion	V COMP STORM MOTION	197	106
Accumulated total precipitation	ACM TOTAL PRECIP	61	1
Accumulated convective precipitation	ACM CONVCTIVE PRECIP	63	1
Accumulated grid-scale	ACM GRD SCALE PRECIP	62	1

precipitation			
Accumulated snowfall	ACM SNOWFALL	65	1
Accumulated total snow melt	ACM SNOW TOTAL MELT	99	1
Precipitation type (4 types) – instantaneous	INSTANT PRECIP TYPE	140	1
Precipitation rate - instantaneous	INSTANT PRECIP RATE	59	1
Composite radar reflectivity	COMPOSITE RADAR REFL	212	200
Low level cloud fraction	LOW CLOUD FRACTION	73	214
Mid level cloud fraction	MID CLOUD FRACTION	74	224
High level cloud fraction	HIGH CLOUD FRACTION	75	234
Total cloud fraction	TOTAL CLD FRACTION	71	200
Time-averaged total cloud fraction	AVG TOTAL CLD FRAC	71	200
Time-averaged stratospheric cloud fraction	AVG STRAT CLD FRAC	213	200
Time-averaged convective cloud fraction	AVG CNVCT CLD FRAC	72	200
Cloud bottom pressure	CLOUD BOT PRESSURE	1	2
Cloud top pressure	CLOUD TOP PRESSURE	1	3
Cloud bottom height (above MSL)	CLOUD BOTTOM HEIGHT	7	2
Cloud top height (above MSL)	CLOUD TOP HEIGHT	7	3
Convective cloud bottom pressure	CONV CLOUD BOT PRESS	1	242
Convective cloud top pressure	CONV CLOUD TOP PRESS	1	243
Shallow convective cloud bottom pressure	SHAL CU CLD BOT PRES	1	248
Shallow convective cloud top pressure	SHAL CU CLD TOP PRES	1	249
Deep convective cloud bottom pressure	DEEP CU CLD BOT PRES	1	251
Deep convective cloud top pressure	DEEP CU CLD TOP PRES	1	252
Grid scale cloud bottom pressure	GRID CLOUD BOT PRESS	1	206
Grid scale cloud top pressure	GRID CLOUD TOP PRESS	1	207
Convective cloud fraction	CONV CLOUD FRACTION	72	200
Convective cloud efficiency	CU CLOUD EFFICIENCY	134	200

Above-ground height of LCL	LCL AGL HEIGHT	7	5
Pressure of LCL	LCL PRESSURE	1	5
Cloud top temperature	CLOUD TOP TEMPS	11	3
Temperature tendency from radiative fluxes	RADFLX CNVG TMP TNDY	216	109
Temperature tendency from shortwave radiative flux	SW RAD TEMP TNDY	250	109
Temperature tendency from longwave radiative flux	LW RAD TEMP TNDY	251	109
Outgoing surface shortwave radiation - instantaneous	INSTN OUT SFC SW RAD	211	1
Outgoing surface longwave radiation - instantaneous	INSTN OUT SFC LW RAD	212	1
Incoming surface shortwave radiation - time-averaged	AVE INCMG SFC SW RAD	204	1
Incoming surface longwave radiation - time-averaged	AVE INCMG SFC LW RAD	205	1
Outgoing surface shortwave radiation - time-averaged	AVE OUTGO SFC SW RAD	211	1
Outgoing surface longwave radiation - time-averaged	AVE OUTGO SFC LW RAD	212	1
Outgoing model top shortwave radiation - time-averaged	AVE OUTGO TOA SW RAD	211	8
Outgoing model top longwave radiation - time-averaged	AVE OUTGO TOA LW RAD	212	8
Incoming surface shortwave radiation - instantaneous	INSTN INC SFC SW RAD	204	1
Incoming surface longwave radiation - instantaneous	INSTN INC SFC LW RAD	205	1
Roughness length	ROUGHNESS LENGTH	83	1
Friction velocity	FRICTION VELOCITY	253	1
Surface drag coefficient	SFC DRAG COEFFICIENT	252	1
Surface u wind stress	SFC U WIND STRESS	124	1
Surface v wind stress	SFC V WIND STRESS	125	1
Surface sensible heat flux - time-averaged	AVE SFC SENHEAT FX	122	1
Ground heat flux - time-averaged	AVE GROUND HEAT FX	155	1
Surface latent heat flux - time-averaged	AVE SFC LATHEAT FX	121	1
Surface momentum flux - time-averaged	AVE SFC MOMENTUM FX	172	1
Accumulated surface	ACC SFC EVAPORATION	57	1

evaporation			
Surface sensible heat flux – instantaneous	INST SFC SENHEAT FX	122	1
Surface latent heat flux - instantaneous	INST SFC LATHEAT FX	121	1
Latitude	LATITUDE	176	1
Longitude	LONGITUDE	177	1
Land sea mask (land=1, sea=0)	LAND/SEA MASK	81	1
Sea ice mask	SEA ICE MASK	91	1
Surface midday albedo	SFC MIDDAY ALBEDO	84	1
Sea surface temperature	SEA SFC TEMPERATURE	80	1
Press at tropopause	PRESS AT TROPOPAUSE	1	7
Temperature at tropopause	TEMP AT TROPOPAUSE	11	7
Potential temperature at tropopause	POTENTL TEMP AT TROP	13	7
U wind at tropopause	U WIND AT TROPOPAUSE	33	7
V wind at tropopause	V WIND AT TROPOPAUSE	34	7
Wind shear at tropopause	SHEAR AT TROPOPAUSE	136	7
Height at tropopause	HEIGHT AT TROPOPAUSE	7	7
Temperature at flight levels	TEMP AT FD HEIGHTS	11	103
U wind at flight levels	U WIND AT FD HEIGHTS	33	103
V wind at flight levels	V WIND AT FD HEIGHTS	34	103
Freezing level height (above mean sea level)	HEIGHT OF FRZ LVL	7	4
Freezing level RH	REL HUMID AT FRZ LVL	52	4
Highest freezing level height	HIGHEST FREEZE LVL	7	204
Pressure in boundary layer (30 mb mean)	PRESS IN BNDRY LYR	1	116
Temperature in boundary layer (30 mb mean)	TEMP IN BNDRY LYR	11	116
Potential temperature in boundary layers (30 mb mean)	POT TMP IN BNDRY LYR	13	116
Dew point temperature in boundary layer (30 mb mean)	DWPT IN BNDRY LYR	17	116
Specific humidity in boundary layer (30 mb mean)	SPC HUM IN BNDRY LYR	51	116
RH in boundary layer (30 mb mean)	REL HUM IN BNDRY LYR	52	116
Moisture convergence in	MST CNV IN BNDRY LYR	135	116

boundary layer (30 mb mean)			
Precipitable water in boundary layer (30 mb mean)	P WATER IN BNDRY LYR	54	116
U wind in boundary layer (30 mb mean)	U WIND IN BNDRY LYR	33	116
V wind in boundary layer (30 mb mean)	V WIND IN BNDRY LYR	34	116
Omega in boundary layer (30 mb mean)	OMEGA IN BNDRY LYR	39	116
Visibility	VISIBILITY	20	1
Vegetation type	VEGETATION TYPE	225	1
Soil type	SOIL TYPE	224	1
Canopy conductance	CANOPY CONDUCTANCE	181	1
PBL height	PBL HEIGHT	221	1
Slope type	SLOPE TYPE	222	1
Snow depth	SNOW DEPTH	66	1
Liquid soil moisture	LIQUID SOIL MOISTURE	160	112
Snow free albedo	SNOW FREE ALBEDO	170	1
Maximum snow albedo	MAXIMUM SNOW ALBEDO	159	1
Canopy water evaporation	CANOPY WATER EVAP	200	1
Direct soil evaporation	DIRECT SOIL EVAP	199	1
Plant transpiration	PLANT TRANSPIRATION	210	1
Snow sublimation	SNOW SUBLIMATION	198	1
Air dry soil moisture	AIR DRY SOIL MOIST	231	1
Soil moist porosity	SOIL MOIST POROSITY	240	1
Minimum stomatal resistance	MIN STOMATAL RESIST	203	1
Number of root layers	NO OF ROOT LAYERS	171	1
Soil moist wilting point	SOIL MOIST WILT PT	219	1
Soil moist reference	SOIL MOIST REFERENCE	230	1
Canopy conductance - solar component	CANOPY COND SOLAR	246	1
Canopy conductance - temperature component	CANOPY COND TEMP	247	1
Canopy conductance - humidity component	CANOPY COND HUMID	248	1
Canopy conductance - soil component	CANOPY COND SOILM	249	1
Potential evaporation	POTENTIAL EVAP	145	1
Heat diffusivity on sigma surface	DIFFUSION H RATE S S	182	107

Surface wind gust	SFC WIND GUST	180	1
Convective precipitation rate	CONV PRECIP RATE	214	1
Radar reflectivity at certain above ground heights	RADAR REFL AGL	211	105
MAPS Sea Level Pressure	MAPS SLP	2	102
Total soil moisture	TOTAL SOIL MOISTURE	86	112
Plant canopy surface water	PLANT CANOPY SFC WTR	223	1
Accumulated storm surface runoff	ACM STORM SFC RNOFF	235	1
Accumulated baseflow runoff	ACM BSFL-GDWR RNOFF	234	1
Fraction of frozen precipitation	FROZEN FRAC CLD SCHM	194	1
GSD Cloud Base pressure	GSD CLD BOT PRESSURE	1	2
GSD Cloud Top pressure	GSD CLD TOP PRESSURE	1	3
Averaged temperature tendency from grid scale latent heat release	AVE GRDSCL RN TMPTDY	241	109
Averaged temperature tendency from convective latent heat release	AVE CNVCT RN TMPTDY	242	109
Average snow phase change heat flux	AVE SNO PHSCNG HT FX	229	1
Accumulated potential evaporation	ACC POT EVAPORATION	228	1
Highest freezing level relative humidity	HIGHEST FRZ LVL RH	52	204
Maximum wind pressure level	MAX WIND PRESS LEVEL	1	6
Maximum wind height	MAX WIND HGHT LEVEL	7	6
U-component of maximum wind	U COMP MAX WIND	33	6
V-component of maximum wind	V COMP MAX WIND	34	6
GSD cloud base height	GSD CLD BOT HEIGHT	7	2
GSD cloud top height	GSD CLD TOP HEIGHT	7	3
GSD visibility	GSD VISIBILITY	20	1
Wind energy potential	INSTN WIND POWER AGL	126	105
U wind at 80 m above ground	U WIND AT 80M AGL	49	105
V wind at 80 m above ground	V WIND AT 80M AGL	50	105
Graupel on model surface	GRAUPEL ON MDL SFCS	179	109
Graupel on pressure surface	GRAUPEL ON P SFCS	179	100

Maximum updraft helicity	MAX UPDRAFT HELICITY	236	106
Maximum 1km reflectivity	MAX 1km REFLECTIVITY	235	105
Maximum wind speed at 10m	MAX 10m WIND SPEED	229	105
Maximum updraft vertical velocity	MAX UPDRAFT VERT VEL	237	101
Maximum downdraft vertical velocity	MAX DNDRAFT VERT VEL	238	101
Mean vertical velocity	MEAN VERT VEL	40	108
Radar echo top in KDT	ECHO TOPS IN KFT	7	105
Updraft helicity	UPDRAFT HELICITY PRM	227	106
Column integrated graupel	VERT INTEG GRAUP	179	200
Column integrated maximum graupel	MAX VERT INTEG GRAUP	228	200
U-component of 0-1km level wind shear	U COMP 0-1 KM SHEAR	230	106
V-component of 0-1km level wind shear	V COMP 0-1 KM SHEAR	238	106
U-component of 0-6km level wind shear	U COMP 0-6 KM SHEAR	239	106
V-component of 0-6km level wind shear	V COMP 0-6 KM SHEAR	241	106
Total precipitation accumulated over user-specified bucket	BUCKET TOTAL PRECIP	61	1
Convective precipitation accumulated over user-specified bucket	BUCKET CONV PRECIP	63	1
Grid-scale precipitation accumulated over user-specified bucket	BUCKET GRDSCALE PRCP	62	1
Snow accumulated over user-specified bucket	BUCKET SNOW PRECIP	65	1
Model level fraction of rain for Ferrier's scheme	F_rain ON MDL SFCS	131	109
Model level fraction of ice for Ferrier's scheme	F_ice ON MDL SFCS	132	109
Model level riming factor for Ferrier's scheme	F_RimeF ON MDL SFCS	133	109
Model level total condensate for Ferrier's scheme	CONDENSATE MDL SFCS	135	109
Height of sigma surface	HEIGHT OF SIGMA SFCS	7	107
Temperature on sigma surface	TEMP ON SIGMA SFCS	11	107
Specific humidity on sigma	SPEC HUM ON S SFCS	51	107

surface			
U-wind on sigma surface	U WIND ON SIGMA SFCS	33	107
V-wind on sigma surface	V WIND ON SIGMA SFCS	34	107
Omega on sigma surface	OMEGA ON SIGMA SFCS	39	107
Cloud water on sigma surface	CLOUD WATR ON S SFCS	153	107
Cloud ice on sigma surface	CLOUD ICE ON S SFCS	58	107
Rain on sigma surface	RAIN ON S SFCS	170	107
Snow on sigma surface	SNOW ON S SFCS	171	107
Condensate on sigma surface	CONDENSATE ON S SFCS	135	107
Pressure on sigma surface	PRESS ON SIG SFCS	1	107
Turbulent kinetic energy on sigma surface	TRBLNT KE ON S SFCS	158	107
Cloud fraction on sigma surface	CLD FRAC ON SIG SFCS	71	107
Graupel on sigma surface	GRAUPEL ON S SFCS	179	107
LCL level pressure	LIFT PCL LVL PRESS	141	116
LOWEST WET BULB ZERO HEIGHT	LOW WET BULB ZERO HT	7	245
Leaf area index	LEAF AREA INDEX	182	1
Accumulated land surface model precipitation	ACM LSM PRECIP	154	1
In-flight icing	IN-FLIGHT ICING	186	100
Clear air turbulence	CLEAR AIR TURBULENCE	185	100
Wind shear between shelter level and 2000 FT	0-2000FT LLWS	136	106
Ceiling	CEILING	7	215
Flight restritction	FLIGHT RESTRICTION	20	2
Instantaneous clear sky incoming surface shortwave	INSTN CLR INC SFC SW	161	1
Pressure level riming factor for Ferrier's scheme	F_RimeF ON P SFCS	133	100
Model level vertical volocity	W WIND ON MDL SFCS	40	109
Brightness temperature	BRIGHTNESS TEMP	213	8
Average albedo	AVE ALBEDO	84	1
Ozone on model surface	OZONE ON MDL SFCS	154	109
Ozone on pressure surface	OZONE ON P SFCS	154	100
Surface zonal momentum flux	SFC ZONAL MOMEN FX	124	1
Surface meridional momentum flux	SFC MERID MOMEN FX	125	1
Average precipitation rate	AVE PRECIP RATE	59	1
Average convective precipitation rate	AVE CONV PRECIP RATE	214	1

Instantaneous outgoing longwave at top of atmosphere	INSTN OUT TOA LW RAD	212	8
Total spectrum brightness temperature	BRIGHTNESS TEMP NCAR	118	8
Model top pressure	MODEL TOP PRESSURE	1	8
Composite rain radar reflectivity	COMPOSITE RAIN REFL	165	200
Composite ice radar reflectivity	COMPOSITE ICE REFL	166	200
Composite radar reflectivity from convection	COMPOSITE CONV REFL	167	200
Rain radar reflecting angle	RAIN RADAR REFL AGL	165	105
Ice radar reflecting angle	ICE RADAR REFL AGL	166	105
Convection radar reflecting angle	CONV RADAR REFL AGL	167	105
Model level vertical velocity	W WIND ON P SFCS	40	100
Column integrated super cool liquid water	TOTAL COLD LIQUID	168	200
Column integrated melting ice	TOTAL MELTING ICE	169	200
Height of lowest level super cool liquid water	COLD LIQ BOT HEIGHT	7	253
Height of highest level super cool liquid water	COLD LIQ TOP HEIGHT	7	254
Richardson number planetary boundary layer height	RICH NO PBL HEIGHT	7	220
Total column shortwave temperature tendency	TOT COL SW T TNDY	250	200
Total column longwave temperature tendency	TOT COL LW T TNDY	251	200
Total column gridded temperature tendency	TOT COL GRD T TNDY	241	200
Total column convective temperature tendency	TOT COL CNVCT T TNDY	242	200
Radiative flux temperature tendency on pressure level	RADFLX TMP TNDY ON P	216	100
Column integrated moisture convergence	TOT COL MST CNVG	135	200
Time averaged clear sky incoming UV-B shortwave	AVE CLR INC UV-B SW	201	1
Time averaged incoming UV-B shortwave	AVE INC UV-B SW	200	1
Total column ozone	TOT COL OZONE	10	200
Average low cloud fraction	AVE LOW CLOUD FRAC	71	214

Average mid cloud fraction	AVE MID CLOUD FRAC	71	224
Average high cloud fraction	AVE HIGH CLOUD FRAC	71	234
Average low cloud bottom pressure	AVE LOW CLOUD BOT P	1	212
Average low cloud top pressure	AVE LOW CLOUD TOP P	1	213
Average low cloud top temperature	AVE LOW CLOUD TOP T	11	213
Average mid cloud bottom pressure	AVE MID CLOUD BOT P	1	222
Average mid cloud top pressure	AVE MID CLOUD TOP P	1	223
Average mid cloud top temperature	AVE MID CLOUD TOP T	11	223
Average high cloud bottom pressure	AVE HIGH CLOUD BOT P	1	232
Average high cloud top pressure	AVE HIGH CLOUD TOP P	1	233
Average high cloud top temperature	AVE HIGH CLOUD TOP T	11	233
Total column relative humidity	TOT COL REL HUM	52	200
Cloud work function	CLOUD WORK FUNCTION	146	200
Temperature at maximum wind level	MAX WIND TEMPERATURE	11	6
Time averaged zonal gravity wave stress	AVE Z GRAVITY STRESS	147	1
Time averaged meridional gravity wave stress	AVE M GRAVITY STRESS	148	1
Average precipitation type	AVE PRECIP TYPE	140	1
Simulated GOES 12 channel 2 brightness temperature	GOES TB – CH 2	213	8
Simulated GOES 12 channel 3 brightness temperature	GOES TB – CH 3	214	8
Simulated GOES 12 channel 4 brightness temperature	GOES TB – CH4	215	8
Simulated GOES 12 channel 5 brightness temperature	GOES TB – CH5	216	8
Cloud fraction on pressure surface	CLD FRAC ON P SFCS	71	100
U-wind on theta surface	U WIND ON THETA SFCS	33	113
V-wind on theta surface	V WIND ON THETA SFCS	34	113
Temperature on theta surface	TEMP ON THETA SFCS	11	113

Potential vorticity on theta surface	PV ON THETA SFCS	4	113
Montgomery streamfunction on theta surface	M STRMFUNC ON THETA	37	113
	S STAB ON THETA SFCS	19	113
Relative humidity on theta surface	RH ON THETA SFCS	52	113
U wind on constant PV surface	U WIND ON PV SFCS	33	117
V wind on constant PV surface	V WIND ON PV SFCS	34	117
Temperature on constant PV surface	TEMP ON PV SFCS	11	117
Height on constant PV surface	HEIGHT ON PV SFCS	7	117
Pressure on constant PV surface	PRESSURE ON PV SFCS	1	117
Wind shear on constant PV surface	SHEAR ON PV SFCS	136	117
Planetary boundary layer cloud fraction	PBL CLD FRACTION	71	211
Average water runoff	AVE WATER RUNOFF	90	1
Planetary boundary layer regime	PBL REGIME	220	1
Maximum 2m temperature	MAX SHELTER TEMP	15	105
Minimum 2m temperature	MIN SHELTER TEMP	16	105
Maximum 2m RH	MAX SHELTER RH	218	105
Minimum 2m RH	MIN SHELTER RH	217	105
Ice thickness	ICE THICKNESS	92	1
Shortwave tendency on pressure surface	SW TNDY ON P SFCS	250	100
Longwave tendency on pressure surface	LW TNDY ON P SFCS	251	100
Deep convective tendency on pressure surface	D CNVCT TNDY ON P SF	242	100
Shallow convective tendency on pressure surface	S CNVCT TNDY ON P SF	244	100
Grid scale tendency on pressure surface	GRDSCL TNDY ON P SFC	241	100
	VDIFF MOIS ON P SFCS	249	100
Deep convective moisture on pressure surface	D CNVCT MOIS ON P SF	243	100
Shallow convective moisture on pressure surface	S CNVCT MOIS ON P SF	245	100

Ozone tendency on pressure surface	OZONE TNDY ON P SFCS	188	100
Mass weighted potential vorticity	MASS WEIGHTED PV	139	100
Simulated GOES 12 channel 3 brightness count	GOES BRIGHTNESS-CH 3	221	8
Simulated GOES 12 channel 4 brightness count	GOES BRIGHTNESS-CH 4	222	8
Omega on theta surface	OMEGA ON THETA SFCS	39	113
Mixing height	MIXHT HEIGHT	67	1
Average clear-sky incoming longwave at surface	AVE CLR INC SFC LW	163	1
Average clear-sky incoming shortwave at surface	AVE CLR INC SFC SW	161	1
Average clear-sky outgoing longwave at surface	AVE CLR OUT SFC LW	162	1
Average clear-sky outgoing longwave at top of atmosphere	AVE CLR OUT TOA LW	162	8
Average clear-sky outgoing shortwave at surface	AVE CLR OUT SFC SW	160	1
Average clear-sky outgoing shortwave at top of atmosphere	AVE CLR OUT TOA SW	160	8
Average incoming shortwave at top of atmosphere	AVE INC TOA SW	204	8
Tranport wind u component	TRANSPORT U WIND	33	220
Transport wind v component	TRANSPORT V WIND	34	220
Sunshine duration	SUNSHINE DURATION	191	1
Field capacity	FIELD CAPACITY	220	1
ICAO height at maximum wind level	ICAO HGHT MAX WIND	5	6
ICAO height at tropopause	ICAO HGHT AT TROP	5	7
Radar echo top	RADAR ECHO TOP	240	200
Time averaged surface Visible beam downward solar flux	AVE IN SFC VIS SW BE	166	1
Time averaged surface Visible diffuse downward solar flux	AVE IN SFC VIS SW DF	167	1
Time averaged surface Near IR beam downward solar flux	AVE IN SFC IR SW BE	168	1
Time averaged surface Near IR diffuse downward solar flux	AVE IN SFC IR SW DF	169	1
Average snowfall rate	AVE SNOWFALL RATE	64	1

Dust 1 on pressure surface	DUST 1 ON P SFCS	240	100
Dust 2 on pressure surface	DUST 2 ON P SFCS	241	100
Dust 3 on pressure surface	DUST 3 ON P SFCS	242	100
Dust 4 on pressure surface	DUST 4 ON P SFCS	243	100
Dust 5 on pressure surface	DUST 5 ON P SFCS	244	100
Equilibrium level height	EQUIL LEVEL HEIGHT	7	247
Lightning	LIGHTNING	187	1
Goes west channel 2 brightness temperature	GOES W TB – CH 2	241	8
Goes west channel 3 brightness temperature	GOES W TB – CH 3	242	8
Goes west channel 4 brightness temperature	GOES W TB – CH 4	243	8
Goes west channel 5 brightness temperature	GOES W TB – CH 5	244	8
In flight icing from NCAR's algorithm	NCAR IN-FLIGHT ICING	168	100
Specific humidity at flight levels	SPE HUM AT FD HEIGHT	51	103
Virtual temperature based convective available potential energy	TV CNVCT AVBL POT EN	202	1
Virtual temperature based convective inhibition	TV CNVCT INHIBITION	201	1
Ventilation rate	VENTILATION RATE	241	220
Haines index	HAINES INDEX	250	1
Simulated GOES 12 channel 2 brightness temperature with satellite angle correction	GOESE TB-2 NON NADIR	213	8
Simulated GOES 12 channel 3 brightness temperature with satellite angle correction	GOESE TB-3 NON NADIR	214	8
Simulated GOES 12 channel 4 brightness temperature with satellite angle correction	GOESE TB-4 NON NADIR	215	8
Simulated GOES 12 channel 5 brightness temperature with satellite angle correction	GOESE TB-5 NON NADIR	216	8
Simulated GOES 11 channel 2 brightness temperature with satellite angle correction	GOESW TB-2 NON NADIR	241	8
Simulated GOES 11 channel 3 brightness temperature with satellite angle correction	GOESW TB-3 NON NADIR	242	8

Simulated GOES 11 channel 4 brightness temperature with satellite angle correction	GOESW TB-4 NON NADIR	243	8
Simulated GOES 11 channel 5 brightness temperature with satellite angle correction	GOESW TB-5 NON NADIR	244	8
Pressure at flight levels	PRESS AT FD HEIGHTS	1	103
Simulated AMSR-E channel 9 brightness temperature	AMSRE TB – CH 9	176	8
Simulated AMSR-E channel 10 brightness temperature	AMSRE TB – CH 10	177	8
Simulated AMSR-E channel 11 brightness temperature	AMSRE TB – CH 11	178	8
Simulated AMSR-E channel 12 brightness temperature	AMSRE TB – CH 12	179	8
SSMI channel 4 brightness temperature	SSMI TB – CH 4	176	8
SSMI channel 5 brightness temperature	SSMI TB – CH 5	177	8
SSMI channel 6 brightness temperature	SSMI TB – CH 6	178	8
SSMI channel 7 brightness temperature	SSMI TB – CH 7	179	8
Time-averaged percentage snow cover	TIME AVG PCT SNW CVR	238	1
Time-averaged surface pressure	TIME AVG SFC PRESS	1	1
Time-averaged 10m temperature	TIME AVG TMP AT 10M	11	105
Time-averaged mass exchange coefficient	TAVG MASS EXCH COEF	185	1
Time-averaged wind exchange coefficient	TAVG WIND EXCH COEF	186	1
Temperature at 10m	TEMP AT 10 M	11	105
Maximum U-component wind at 10m	U COMP MAX 10 M WIND	253	105
Maximum V-component wind at 10m	V COMP MAX 10 M WIND	254	105

Chapter 7: Test Cases

Table of Contents

Introduction

The NMMB friendly-user release provided by DTC/NCAR comes with three different test cases. These test cases were created in order to sample different modeling scenarios, such as using nested domains and different physics combinations.

Description of Test Cases

The test cases are as follows:

test.1dom/npsprd - has an example test case for a single domain NPS run
test.1dom/nmbprd - has an example test case for a single domain NEMS/NMMB run
test.1dom/postprd - has an example grads script to plot T10

test.2dom/npsprd - has an example test case for a nested 2-domain NPS run
test.2dom/nmbprd - has an example test case for a nested 2-domain NEMS/NMMB run

test.ThompsonMP/npsprd - has an example test case for a 3-domain case, using GWD and ncep_processing
test.ThompsonMP/nmbprd - has an example test case for a 3-domain case, using Thompson microphysics and RRTM radiation

Test cases increase in complexity from one to three, however the instructions are the same for each.

Basic Steps

The following steps outline the workflow for each test case:

1. Set up namelist/config files for NPS and NMMB
   NPS: namelist.nps
   NMMB: configure_file_01 (and _02, etc for nested domains)
   Note - There is also a script that will create a namelist.nps from templates: build_namelists.scr
2. Link in the GRIB files (GFS, NAM, etc)
3. Run ungrib, geogrid, metgrid
4. Run nemsinterp.exe --- this is the same functionality as real_nmm.exe in WRF - but is part of the init/pre-processing software package (rather than the model)
5. Run the forecast model (NEMS.x)
6. Run UPP or GrADS to visualize the model output

Running NPS

The following commands/steps are necessary to run NPS:

setenv NPS_DIR <your-top-dir>/NMMB_init/NPS

cd test.1dom/npsprd

confirm namelist.nps has:

   geog_data_path = '<your-top-dir>/geog'
   ncep_proc_path = '<your-top-dir>/geog'

===============
NOTE: Additional for Thompson case:
      this test uses "ncep_processing=.true.", so add this link prior to geogrid.exe
      ln -s testb.nml fort.81
      AND change the data paths in testb.nml to match your geog directory!
===============

ln -sf $NPS_DIR/geogrid/GEOGRID.TBL.NMB GEOGRID.TBL
ln -sf $NPS_DIR/geogrid.exe .

ln -sf $NPS_DIR/ungrib/Variable_Tables/Vtable.GFS_with_isobaric.pre20150114 Vtable
--OR--
ln -sf $NPS_DIR/ungrib/Variable_Tables/Vtable.GFS_with_isobaric.post20150114 Vtable

ln -sf $NPS_DIR/ungrib.exe .
ln -sf $NPS_DIR/metgrid/METGRID.TBL.NMB METGRID.TBL
ln -sf $NPS_DIR/metgrid.exe .

ln -sf $NPS_DIR/nemsinterp.exe .

$NPS_DIR/link_grib.csh <your-top-dir>/TestCases/GFS/20131104/gfs*
--OR--
$NPS_DIR/link_grib.csh <your-top-dir>/TestCases/GFS/2016020200/gfs*

RUN the executables using a simple bsub script (edit for your project # if necessary)

===============
NOTE: a sample "qsub" script is also provided for jet/theia
===============

bsub < run_geogrid.csh
bsub < run_ungrib.csh
bsub < run_metgrid.csh
bsub < run_nemsinterp.csh

RESULTS:

Initial conditions: input_domain_01* (and 02, etc for nests)
Boundary conditions: boco.NNNN
configure_nest_details_01 (and 02, etc)
domain_details_01 (and 02, etc)

Running NEMS/NMMB

The following commands/steps are necessary to run NEMS/NMMB:

cd ../nmbprd

ln -s configure_file_d01 model_configure #NOTE: already done in the examples
ln -sf <your-top-dir>/NEMS/exe/NEMS.x .
ln -sf <your-top-dir>/TABLES/* .
ln -sf ../npsprd/input_domain_0* .
ln -sf ../npsprd/boco.00* .

===============
NOTE: Additional for 2dom and Thompson cases:
  ln -s global_o3prdlos.f77 fort.28
  ln -s global_o3clim.txt fort.48
  ln -sf ../npsprd/GWD* .

Since the Thompson test case uses the IGBP land use data, different tables are needed!

```
#  Remove the links for VEG/LAND tables:
   rm VEGPARM.TBL
   rm LANDUSE.TBL
   cp IGBP_VEGPARM.TBL VEGPARM.TBL
   cp IGBP_LANDUSE.TBL LANDUSE.TBL
===============
```

bsub < run_nmb.csh

RESULTS:

nmmb_hst*

The output files are named with forecast offset/tau (NOT with the valid time of the forecast!)

Generating Basic Graphics Using GrADS

The native output format from NEMS is "nemsio", which is binary. Option 1 is to run UPP to get a GRIB file and then use your favorite grib viewer (NCL). Option 2 is to use GrADS to read/plot the native files - a GrADS control file is generated with each NMMB output file.

The following commands/steps are necessary to plot graphics using GrADS:

```
cd postprd
ln -s ../nmbprd/nmmb_hst* .
module load grads
grads -l -b -c 'run nmmbvis'

gxps -c -i nmmbvis.gmf -o t10.ps
convert -rotate 90 t10.ps t10.png
display t10.png
```

Edit nmmbvis.gs in order to select other variables, maps, etc.

Appendix 1

NPS Output Fields

Below is a listing of global attributes and fields written to geogrid output files. This listing is produced from the diodump program when run on a typical geo_nmb.d01.dio file:

```
NPS/dio/diodump.exe geo_nmb.d01.dio
       1 geo_nmb.d01.dio
 my_endianness =          2
 is_little_endian() = T
 File: geo_nmb.d01.dio opened
             1 TITLE                                       1      501
  1 TITLE                           1 501 OUTPUT FROM GRIDGEN
  2 SIMULATION_START_DATE           1 501 0000-00-00_00:00:00
  3 WEST-EAST_GRID_DIMENSION        0 103         5
  4 SOUTH-NORTH_GRID_DIMENSION      0 103         5
  5 BOTTOM-TOP_GRID_DIMENSION       0 103         0
  6 WEST-EAST_PATCH_START_UNSTAG    0 103         1
  7 WEST-EAST_PATCH_END_UNSTAG      0 103         5
  8 WEST-EAST_PATCH_START_STAG      0 103         1
  9 WEST-EAST_PATCH_END_STAG        0 103         5
 10 SOUTH-NORTH_PATCH_START_UNSTAG  0 103         1
 11 SOUTH-NORTH_PATCH_END_UNSTAG    0 103         5
 12 SOUTH-NORTH_PATCH_START_STAG    0 103         1
 13 SOUTH-NORTH_PATCH_END_STAG      0 103         5
 14 GRIDTYPE                        1 501 B
 15 DX                              0 204  0.1218329966E+00
 16 DY                              0 204  0.1218329966E+00
 17 DYN_OPT                         0 103         4
 18 CEN_LAT                         0 204  0.4750000000E+02
 19 CEN_LON                         0 204 -0.1040000000E+03
 20 TRUELAT1                        0 204  0.4750000000E+02
 21 TRUELAT2                        0 204  0.4750000000E+02
 22 MOAD_CEN_LAT                    0 204  0.0000000000E+00
```

```
 23 STAND_LON                           0 204 -0.1040000000E+03
 24 corner_lats                         1 204  0.0000000000E+00 0.4780426407E+02
 25 corner_lons                         1 204 -0.1043623505E+03
0.0000000000E+00
 26 MAP_PROJ                            0 103         204
 27 MMINLU                              1 501 USGS
 28 ISWATER                             0 103         16
 29 ISICE                               0 103         24
 30 ISURBAN                             0 103         1
 31 ISOILWATER                          0 103         14
 32 grid_id                             0 103         1
 33 parent_id                           0 103         0
 34 i_parent_start                      0 103         0
 35 j_parent_start                      0 103         0
 36 i_parent_end                        0 103         0
 37 j_parent_end                        0 103         0
 38 parent_grid_ratio                   0 103         1
 39 XLAT_M                              3 204(  1:  5,  1:  5,  1:  1)
      0.4725577164E+02    0.4774366760E+02
 40 XLONG_M                             3 204(  1:  5,  1:  5,  1:  1)   -
0.1043623505E+03   -0.1036376495E+03
 41 XLAT_V                              3 204(  1:  5,  1:  5,  1:  1)
      0.4731637192E+02    0.4780454636E+02
 42 XLONG_V                             3 204(  1:  5,  1:  5,  1:  1)   -
0.1042720795E+03   -0.1035465317E+03
 43 E                                   3 204(  1:  5,  1:  5,  1:  1)
      0.9806990420E-04    0.9898551070E-04
 44 F                                   3 204(  1:  5,  1:  5,  1:  1)
      0.1071035585E-03    0.1079425710E-03
 45 LANDMASK                            3 204(  1:  5,  1:  5,  1:  1)
      0.1000000000E+01    0.1000000000E+01
 46 LANDUSEF                            3 204(  1:  5,  1:  5,  1: 24)
      0.0000000000E+00    0.1000000000E+01
 47 LU_INDEX                            3 204(  1:  5,  1:  5,  1:  1)
      0.2000000000E+01    0.7000000000E+01
 48 HGT_M                               3 204(  1:  5,  1:  5,  1:  1)
      0.6377104492E+03    0.7604421387E+03
 49 HGT_V                               3 204(  1:  5,  1:  5,  1:  1)
      0.6445386963E+03    0.7513249512E+03
 50 SOILTEMP                            3 204(  1:  5,  1:  5,  1:  1)
      0.2844074402E+03    0.2854859009E+03
 51 SOILCTOP                            3 204(  1:  5,  1:  5,  1: 16)
      0.0000000000E+00    0.1000000000E+01
 52 SOILCBOT                            3 204(  1:  5,  1:  5,  1: 16)
      0.0000000000E+00    0.1000000000E+01
 53 ALBEDO12M                           3 204(  1:  5,  1:  5,  1: 12)
      0.1000102520E+02    0.1400000000E+02
 54 GREENFRAC                           3 204(  1:  5,  1:  5,  1: 12)
      0.9999999776E-02    0.4579406679E+00
 55 SNOALB                              3 204(  1:  5,  1:  5,  1:  1)
      0.7155805206E+02    0.7479289246E+02
 56 SLOPECAT                            3 204(  1:  5,  1:  5,  1:  1)
      0.1000000000E+01    0.3000000000E+01
 57 HGTSTDV                             3 204(  1:  5,  1:  5,  1:  1)
      0.5970137329E+03    0.7934624023E+03
 58 HGTMAX                              3 204(  1:  5,  1:  5,  1:  1)
      0.5970137329E+03    0.7934624023E+03
 59 HGTSGMA                             3 204(  1:  5,  1:  5,  1:  1)
      0.5970137329E+03    0.7934624023E+03
```

```
 60 HGTCNVX                          3 204(  1:  5,  1:  5,  1:  1)
      0.5970137329E+03    0.7934624023E+03
 61 HGTGMMA                          3 204(  1:  5,  1:  5,  1:  1)
      0.5970137329E+03    0.7934624023E+03
 62 HGTTHTA                          3 204(  1:  5,  1:  5,  1:  1)
      0.5970137329E+03    0.7934624023E+03
 63 HGTOA1                           3 204(  1:  5,  1:  5,  1:  1)
      0.5970137329E+03    0.7934624023E+03
 64 HGTOA2                           3 204(  1:  5,  1:  5,  1:  1)
      0.5970137329E+03    0.7934624023E+03
 65 HGTOA3                           3 204(  1:  5,  1:  5,  1:  1)
      0.5970137329E+03    0.7934624023E+03
 66 HGTOA4                           3 204(  1:  5,  1:  5,  1:  1)
      0.5970137329E+03    0.7934624023E+03
 67 HGTOL1                           3 204(  1:  5,  1:  5,  1:  1)
      0.5970137329E+03    0.7934624023E+03
 68 HGTOL2                           3 204(  1:  5,  1:  5,  1:  1)
      0.5970137329E+03    0.7934624023E+03
 69 HGTOL3                           3 204(  1:  5,  1:  5,  1:  1)
      0.5970137329E+03    0.7934624023E+03
 70 HGTOL4                           3 204(  1:  5,  1:  5,  1:  1)
      0.5970137329E+03    0.7934624023E+03
```

In addition to the fields in a geogrid output file (e.g., geo_nmb.d01.dio), the following fields and global attributes will also be present in a typical output file from the metgrid program, run with the default METGRID.TBL file and meteorological data from NCEP's GFS model.

```
NPS/dio/diodump met_nmb.d01.2011-01-30_00\:00\:00.dio
            1 met_nmb.d01.2013-01-30_12:00:00.dio
  1 TITLE                          1 501 OUTPUT FROM METGRID
  2 SIMULATION_START_DATE          1 501 2013-01-30_12:00:00
  3 WEST-EAST_GRID_DIMENSION       0 103       5
  4 SOUTH-NORTH_GRID_DIMENSION     0 103       5
  5 BOTTOM-TOP_GRID_DIMENSION      0 103       27
  6 WEST-EAST_PATCH_START_UNSTAG   0 103       1
  7 WEST-EAST_PATCH_END_UNSTAG     0 103       5
  8 WEST-EAST_PATCH_START_STAG     0 103       1
  9 WEST-EAST_PATCH_END_STAG       0 103       5
 10 SOUTH-NORTH_PATCH_START_UNSTAG  0 103       1
 11 SOUTH-NORTH_PATCH_END_UNSTAG   0 103       5
 12 SOUTH-NORTH_PATCH_START_STAG   0 103       1
 13 SOUTH-NORTH_PATCH_END_STAG     0 103       5
 14 GRIDTYPE                       1 501 B
 15 DX                             0 204 0.1218329966E+00
 16 DY                             0 204 0.1218329966E+00
 17 DYN_OPT                        0 103       4
 18 CEN_LAT                        0 204 0.4750000000E+02
 19 CEN_LON                        0 204 -0.1040000000E+03
 20 TRUELAT1                       0 204       0.4750000000E+02
 21 TRUELAT2                       0 204 0.4750000000E+02
 22 MOAD_CEN_LAT                   0 204 0.0000000000E+00
 23 STAND_LON                      0 204 -0.1040000000E+03
 24 corner_lats                    1 204 0.0000000000E+00
0.4780426407E+02
```

```
25 corner_lons                      1 204 -0.1043623505E+03
     0.0000000000E+00
26 MAP_PROJ                         0 103       204
27 MMINLU                           1 501 USGS
28 ISWATER                          0 103       16
29 ISICE                            0 103       24
30 ISURBAN                          0 103       1
31 ISOILWATER                       0 103       14
32 grid_id                          0 103       1
33 parent_id                        0 103       0
34 i_parent_start                   0 103       0
35 j_parent_start                   0 103       0
36 i_parent_end                     0 103       0
37 j_parent_end                     0 103       0
38 parent_grid_ratio                0 103       1
39 FLAG_METGRID                     0 103       1
40 FLAG_PSFC                        0 103       1
41 FLAG_SM000010                    0 103       1
42 FLAG_SM010040                    0 103       1
43 FLAG_SM040100                    0 103       1
44 FLAG_SM100200                    0 103       1
45 FLAG_ST000010                    0 103       1
46 FLAG_ST010040                    0 103       1
47 FLAG_ST040100                    0 103       1
48 FLAG_ST100200                    0 103       1
49 FLAG_SOILHGT                     0 103       1
50 PRES                             3 204(  1:  5,  1:  5,  1: 27)
     0.1000000000E+04  0.1000000000E+06
51 SMC_WPS                          3 204(  1:  5,  1:  5,  1:  4)
     0.1898772418E+00  0.4155691266E+00
52 STC_WPS                          3 204(  1:  5,  1:  5,  1:  4)
     0.2655249023E+03  0.2777678833E+03
53 CLWMR                            3 204(  1:  5,  1:  5,  1: 27)
     0.0000000000E+00  0.2800000038E-04
54 GHT                              3 204(  1:  5,  1:  5,  1: 27)
     0.2068354797E+03  0.3048988672E+05
55 SNOW                             3 204(  1:  5,  1:  5,  1:  1)
     0.1300000000E+02  0.1348845673E+02
56 SKINTEMP                         3 204(  1:  5,  1:  5,  1:  1)
     0.2486893768E+03  0.2500295563E+03
57 SOILHGT                          3 204(  1:  5,  1:  5,  1:  1)
     0.6709074707E+03  0.7581098633E+03
58 LANDSEA                          3 204(  1:  5,  1:  5,  1:  1)
     0.1000000000E+01  0.1000000000E+01
59 SEAICE                           3 204(  1:  5,  1:  5,  1:  1)
     0.0000000000E+00  0.0000000000E+00
60 ST100200                         3 204(  1:  5,  1:  5,  1:  1)
     0.2770410767E+03  0.2777678833E+03
61 ST040100                         3 204(  1:  5,  1:  5,  1:  1)
     0.2727278442E+03  0.2740977173E+03
62 ST010040                         3 204(  1:  5,  1:  5,  1:  1)
     0.2700708618E+03  0.2713269958E+03
63 ST000010                         3 204(  1:  5,  1:  5,  1:  1)
     0.2655249023E+03  0.2675628052E+03
```

```
 64 SM100200                          3 204(  1:  5,  1:  5,  1:  1)
     0.1898772418E+00  0.1939784884E+00
 65 SM040100                          3 204(  1:  5,  1:  5,  1:  1)
     0.1909649074E+00  0.1940348893E+00
 66 SM010040                          3 204(  1:  5,  1:  5,  1:  1)
     0.2148802280E+00  0.2272721976E+00
 67 SM000010                          3 204(  1:  5,  1:  5,  1:  1)
     0.3566130400E+00  0.4155691266E+00
 68 PSFC                              3 204(  1:  5,  1:  5,  1:  1)
     0.9280573438E+05  0.9389117188E+05
 69 RH                                3 204(  1:  5,  1:  5,  1: 27)
     0.1707398295E+00  0.7877899170E+02
 70 VV                                3 204(  1:  5,  1:  5,  1: 27)    -
0.3030307579E+02   -0.8504756093E+00
 71 UU                                3 204(  1:  5,  1:  5,  1: 27)    -
0.1071965694E+02  0.1666118431E+02
 72 TT                                3 204(  1:  5,  1:  5,  1: 27)
     0.2108749847E+03  0.2577134399E+03
 73 PMSL                              3 204(  1:  5,  1:  5,  1:  1)
     0.1028195000E+06  0.1028739375E+06
 74 HGTOL4                            3 204(  1:  5,  1:  5,  1:  1)
     0.5970137329E+03  0.7934624023E+03
 75 HGTOL3                            3 204(  1:  5,  1:  5,  1:  1)
     0.5970137329E+03  0.7934624023E+03
 76 HGTOL2                            3 204(  1:  5,  1:  5,  1:  1)
     0.5970137329E+03  0.7934624023E+03
 77 HGTOL1                            3 204(  1:  5,  1:  5,  1:  1)
     0.5970137329E+03  0.7934624023E+03
 78 HGTOA4                            3 204(  1:  5,  1:  5,  1:  1)
     0.5970137329E+03  0.7934624023E+03
 79 HGTOA3                            3 204(  1:  5,  1:  5,  1:  1)
     0.5970137329E+03  0.7934624023E+03
 80 HGTOA2                            3 204(  1:  5,  1:  5,  1:  1)
     0.5970137329E+03  0.7934624023E+03
 81 HGTOA1                            3 204(  1:  5,  1:  5,  1:  1)
     0.5970137329E+03  0.7934624023E+03
 82 HGTTHTA                           3 204(  1:  5,  1:  5,  1:  1)
     0.5970137329E+03  0.7934624023E+03
 83 HGTGMMA                           3 204(  1:  5,  1:  5,  1:  1)
     0.5970137329E+03  0.7934624023E+03
 84 HGTCNVX                           3 204(  1:  5,  1:  5,  1:  1)
     0.5970137329E+03  0.7934624023E+03
 85 HGTSGMA                           3 204(  1:  5,  1:  5,  1:  1)
     0.5970137329E+03  0.7934624023E+03
 86 HGTMAX                            3 204(  1:  5,  1:  5,  1:  1)
     0.5970137329E+03  0.7934624023E+03
 87 HGTSTDV                           3 204(  1:  5,  1:  5,  1:  1)
     0.5970137329E+03  0.7934624023E+03
 88 SLOPECAT                          3 204(  1:  5,  1:  5,  1:  1)
     0.1000000000E+01  0.3000000000E+01
 89 SNOALB                            3 204(  1:  5,  1:  5,  1:  1)
     0.7155805206E+02  0.7479289246E+02
 90 GREENFRAC                         3 204(  1:  5,  1:  5,  1: 12)
     0.9999999776E-02  0.4579406679E+00
```

```
 91 ALBEDO12M                       3 204(  1:  5,  1:  5,  1: 12)
      0.1000102520E+02  0.1400000000E+02
 92 SOILCBOT                        3 204(  1:  5,  1:  5,  1: 16)
      0.0000000000E+00  0.1000000000E+01
 93 SOILCTOP                        3 204(  1:  5,  1:  5,  1: 16)
      0.0000000000E+00  0.1000000000E+01
 94 SOILTEMP                        3 204(  1:  5,  1:  5,  1:  1)
      0.2844074402E+03  0.2854859009E+03
 95 HGT_V                           3 204(  1:  5,  1:  5,  1:  1)
      0.6445386963E+03  0.7513249512E+03
 96 HGT_M                           3 204(  1:  5,  1:  5,  1:  1)
      0.6377104492E+03  0.7604421387E+03
 97 LU_INDEX                        3 204(  1:  5,  1:  5,  1:  1)
      0.2000000000E+01  0.7000000000E+01
 98 LANDUSEF                        3 204(  1:  5,  1:  5,  1: 24)
      0.0000000000E+00  0.1000000000E+01
 99 LANDMASK                        3 204(  1:  5,  1:  5,  1:  1)
      0.1000000000E+01  0.1000000000E+01
100 F                               3 204(  1:  5,  1:  5,  1:  1)
      0.1071035585E-03  0.1079425710E-03
101 E                               3 204(  1:  5,  1:  5,  1:  1)
      0.9806990420E-04  0.9898551070E-04
102 XLONG_V                         3 204(  1:  5,  1:  5,  1:  1)   -
0.1042720795E+03   -0.1035465317E+03
103 XLAT_V                          3 204(  1:  5,  1:  5,  1:  1)
      0.4731637192E+02  0.4780454636E+02
104 XLONG_M                         3 204(  1:  5,  1:  5,  1:  1)   -
0.1043623505E+03   -0.1036376495E+03
105 XLAT_M                          3 204(  1:  5,  1:  5,  1:  1)
      0.4725577164E+02  0.4774366760E+02
```