8.1 Purpose

- This is the numerical weather prediction part of the modeling system.

- MM5 can be used for a broad spectrum of theoretical and real-time studies, including applications of both predictive simulation and four-dimensional data assimilation to monsoons, hurricanes, and cyclones.

- On the smaller meso-beta and meso-gamma scales (2-200 km), MM5 can be used for studies involving mesoscale convective systems, fronts, land-sea breezes, mountain-valley circulations, and urban heat islands.

8.2 Basic Equations of MM5

In terms of terrain following coordinates \((x, y, \sigma)\), these are the equations for the nonhydrostatic model’s basic variables excluding moisture.

**Pressure**

\[
\frac{\partial p'}{\partial t} - \rho_0 g w + \gamma p \nabla \cdot \mathbf{V} = -\mathbf{V} \cdot \nabla p' + \frac{\gamma p}{T} \left( \frac{\dot{Q}}{c_p} + \frac{T_0}{\theta_0} D_\theta \right) \]

(8.1)
Momentum (x-component)

\[
\frac{\partial u}{\partial t} + \frac{m}{\rho} \left( \frac{\partial p'}{\partial x} - \frac{\sigma}{p^*} \frac{\partial p'}{\partial \sigma} \right) = -\mathbf{V} \cdot \nabla u + v \left( f + u \frac{\partial m}{\partial y} - v \frac{\partial m}{\partial x} \right) - e_w \cos \alpha - \frac{u w}{r_{\text{earth}}} + D_u \tag{8.2}
\]

Momentum (y-component)

\[
\frac{\partial v}{\partial t} + \frac{m}{\rho} \left( \frac{\partial p'}{\partial y} - \frac{\sigma}{p^*} \frac{\partial p'}{\partial \sigma} \right) = -\mathbf{V} \cdot \nabla v - u \left( f + u \frac{\partial m}{\partial y} - v \frac{\partial m}{\partial x} \right) + e_w \sin \alpha - \frac{v w}{r_{\text{earth}}} + D_v \tag{8.3}
\]

Momentum (z-component)

\[
\frac{\partial w}{\partial t} + \rho_0 \frac{g}{\rho} \frac{\partial p'}{\partial \sigma} + \frac{g p'}{\gamma p} = -\mathbf{V} \cdot \nabla w + g \frac{P_0 T'}{T_0} - \frac{g R_d p'}{c_p p} + e \left( u \cos \alpha - v \sin \alpha \right) + \frac{u^2 + v^2}{r_{\text{earth}}} + D_w \tag{8.4}
\]

Thermodynamics

\[
\frac{\partial T}{\partial t} = -\mathbf{V} \cdot \nabla T + \frac{1}{\rho c_p} \left( \frac{\partial p'}{\partial t} + \mathbf{V} \cdot \nabla p' - \rho_0 g w \right) + \frac{\dot{Q}}{c_p} + \frac{T_0}{\theta_0} \frac{\partial D_\theta}{\partial t} \tag{8.5}
\]

Advection terms can be expanded as

\[
\mathbf{V} \cdot \nabla A \equiv m \frac{\partial A}{\partial x} + m v \frac{\partial A}{\partial y} + \sigma \frac{\partial A}{\partial \sigma} \tag{8.6}
\]

where

\[
\sigma = -\frac{\rho_0 g}{p^* w} - \frac{m \sigma \partial p^*}{p^* \partial x} u - \frac{m \sigma \partial p^*}{p^* \partial y} v \tag{8.7}
\]

Divergence term can be expanded as

\[
\cdot \mathbf{V} = m \frac{2 \frac{\partial}{\partial x} \left( \frac{u}{m} \right)}{p^* \partial x \partial \sigma} - \frac{m \sigma \partial p^*}{p^* \partial x \partial \sigma} + m \frac{2 \frac{\partial}{\partial y} \left( \frac{v}{m} \right)}{p^* \partial y \partial \sigma} - \frac{m \sigma \partial p^*}{p^* \partial y \partial \sigma} - \frac{\rho_0 g \partial w}{p^* \partial \sigma} \tag{8.8}
\]
Notes about the equations:

- **Appendix A** shows derivations of Equations 8.1, 8.4, 8.5 and 8.7, and shows the coordinate transformation from z to sigma coordinates.

- In the model, Equation 8.1 does not include the last term with parentheses on the right. This is neglected and it represents a pressure increase due to heating which forces the air to expand.

- Equations 8.2-8.4 include terms (eu and ew) representing the usually neglected component of the Coriolis force, where \( e = 2\Omega \cos \lambda \), \( \alpha = \phi - \phi_c \), \( \lambda \) is latitude, \( \phi \) is longitude, and \( \phi_c \) is central longitude.

- The \( \frac{\partial m}{\partial y} \), \( \frac{\partial m}{\partial x} \) and \( r_{\text{earth}} \) terms represent curvature effects, and \( m \) is map-scale factor.

- Equations 8.2, 8.3 and 8.8 include terms to account for the sloped sigma surfaces when calculating horizontal gradients.

- Prognostic equations also exist for water vapor and microphysical variables such as cloud and precipitation (if used). These include the advection and various source/sink terms.

**Spatial finite differencing -**
The above equations are finite differenced on the B grid mentioned in Chapter 1. Second-order centered finite differences represent the gradients except for the precipitation fall term which uses a first-order upstream scheme for positive definiteness. Often horizontal averaging is required to determine the gradient in the correct position. Vertical interpolations allow for the variable vertical grid size. More details are in Grell et al. (1994), NCAR Tech. Note 398.

**Temporal finite differencing -**
A second-order leapfrog time-step scheme is used for these equations, but some terms are handled using a time-splitting scheme. Note that Equations 8.1-8.4 contain extra terms on the left of the equals sign. This designates so-called fast terms that are responsible for sound waves that have to be calculated on a shorter time step. In the leapfrog scheme, the tendencies at time \( n \) are used to step the variables from time \( n-1 \) to \( n+1 \). This is used for most of the right-hand terms (advection, Coriolis, buoyancy). A forward step is used for diffusion and microphysics where the tendencies are calculated at time \( n-1 \) and used to step the variables from \( n-1 \) to \( n+1 \). Some radiation and cumulus options use a constant tendency over periods of many model timesteps and are only recalculated every 30 minutes or so.

However for certain terms the model timestep is too long for stability and these have to be predicted with a shorter step. Examples of this are the sound-wave terms shown in the equations, the precipitation fall term and the PBL tendencies which also may be split in certain situations. When the timestep is split, certain variables and tendencies are updated more frequently. For sound waves \( u, v, w \) and \( p' \) all need to be updated each short step using the tendency terms on the left of 8.1-8.4 while the terms on the right are kept fixed. For sound waves there are usually four of these steps between \( n-1 \) and \( n+1 \), after which \( u, v, w \) and \( p' \) are up to date.
Certain processes are treated implicitly for numerical stability. An implicit time scheme is one in which the tendencies of variables depend not only on the present and past values, but also the future values. These schemes are often numerically stable for all timesteps, but usually require a matrix inversion to implement them. In MM5 implicit schemes are used only in 1-d column calculations for vertical sound waves and vertical diffusion, so that the matrix is tridiagonal making it straightforward to solve directly.

**First time step:**

![Diagram of first time step]

**Time step n:**

- T, qv, qc, etc., advection, physics, boundary, coriolis, diffusion terms

![Diagram of time step n]

- u, v, w, p’ advanced (pressure gradients, divergence terms)

**Time step n+1:**

![Diagram of time step n+1]
8.3 Physics Options in MM5

8.3.1 Cumulus Parameterizations (ICUPA)

1. **None** -
   Use no cumulus parametrization at grid sizes < 5-10 km.

2. **Anthes-Kuo** -
   based on moisture convergence, mostly applicable to larger grid sizes > 30 km. Tends to produce much convective rainfall, less resolved-scale precip, specified heating profile, moistening dependent upon relative humidity.

3. **Grell** -
   based on rate of destabilization or quasi-equilibrium, simple single-cloud scheme with updraft and downdraft fluxes and compensating motion determining heating/moistening profile. Useful for smaller grid sizes 10-30 km, tends to allow a balance between resolved scale rainfall and convective rainfall. Shear effects on precipitation efficiency are considered.

4. **Arakawa-Schubert** -
   multi-cloud scheme that is otherwise likeGrell scheme. Based on a cloud population, allowing for entrainment into updrafts and allows for downdrafts. Suitable for larger scales, > 30 km grid sizes, possibly expensive compared to other schemes. Shear effects on precipitation efficiency are considered.
5. Fritsch-Chappell -
Based on relaxation to a profile due to updraft, downdraft and subsidence region properties. The convective mass flux removes 50% of available buoyant energy in the relaxation time. Fixed entrainment rate. Suitable for 20-30 km scales due to single-cloud assumption and local subsidence. See Fritsch and Chappell (1980) and Fritsch and Kain (1993) for details. This scheme predicts both updraft and downdraft properties and also detrains cloud and precipitation. Shear effects on precipitation efficiency are also considered.

6. Kain-Fritsch -
Similar to Fritsch-Chappell, but using a sophisticated cloud-mixing scheme to determine entrainment/detrainment, and removing all available buoyant energy in the relaxation time. See Kain and Fritsch (1993) for details. This scheme predicts both updraft and downdraft properties and also detrains cloud and precipitation. Shear effects on precipitation efficiency are also considered.

7. Betts-Miller -
Based on relaxation adjustment to a reference post-convective thermodynamic profile over a given period. This scheme is suitable for > 30 km, but no explicit downdraft, so may not be suitable for severe convection. See Betts (1986), Betts and Miller (1986), Betts and Miller (1993) and Janjic (1994) for details.

Shallow Cumulus - (ISHALLO=1)
Handles non-precipitating clouds. Assumed to have strong entrainment and small radius, no downdrafts, and uniform clouds. Based on Grell and Arakawa-Schubert schemes. Equilibrium assumption between cloud strength and sub-grid (PBL) forcing.

8.3.2 PBL Schemes (IBLTYP)

0. None -
No surface layer, unrealistic in real-data simulations.
1. **Bulk PBL** -
suitable for coarse vertical resolution in boundary layer, e.g. > 250 m vertical grid sizes. Two stability regimes.

2. **High-resolution Blackadar PBL** -
suitable for high resolution PBL, e.g. 5 layers in lowest km, surface layer < 100 m thick. Four stability regimes, including free convective mixed layer. Uses split time steps for stability.

3. **Burk-Thompson PBL** -
suitable for coarse and high-resolution PBL. Predicts turbulent kinetic energy for use in vertical mixing, based on Mellor-Yamada formulas. See Burk and Thompson (1989) for details. This is the only PBL option that does not call the SLAB scheme, as it has its own force-restore ground temperature prediction.

4. **Eta PBL** -
This is the Mellor-Yamada scheme as used in the Eta model, Janjic (1990, MWR) and Janjic (1994, MWR). It predicts TKE and has local vertical mixing. The scheme calls the SLAB routine for surface temperature and has to use ISOIL=1 because of its long time step. Its cost is between the MRFPBL and HIRPBL schemes. Before SLAB the scheme calculates exchange coefficients.
using similarity theory, and after SLAB it calculates vertical fluxes with an implicit diffusion scheme.

5. MRF PBL -

or Hong-Pan PBL, suitable for high-resolution in PBL (as for Blackadar scheme). Efficient scheme based on Troen-Mahrt representation of countergradient term and K profile in the well mixed PBL, as implemented in the NCEP MRF model. See Hong and Pan (1996) for details. This scheme also calls the SLAB routine and should also have ISOIL=1. Vertical diffusion uses an implicit scheme to allow longer time steps.

6. Gayno-Seaman PBL -

This is also based on Mellor-Yamada TKE prediction. It is distinguished from others by the use of liquid-water potential temperature as a conserved variable, allowing the PBL to operate more accurately in saturated conditions (Ballard et al., 1991). Its cost is comparable with the Blackadar scheme’s because it uses split time steps.

8.3.3 Explicit Moisture Schemes (IMPHYS)

1. Dry -

No moisture prediction. Zero water vapor.

2. Stable Precip -

Nonconvective precipitation. Large scale saturation removed and rained out immediately. No rain evaporation or explicit cloud prediction.
3. Warm Rain -
Cloud and rain water fields predicted explicitly with microphysical processes. No ice phase processes.

4. Simple Ice (Dudhia) -
Adds ice phase processes to above without adding memory. No supercooled water and immediate melting of snow below freezing level. This also can be run with a look-up table (MPHYSTBL=1) version for efficiency.
5. **Mixed-Phase (Reisner)** -
Add supercooled water to above and allows for slow melting of snow. Memory added for cloud ice and snow. No graupel or riming processes. See Reisner et al. (1993, 1996) for details. This also can be run with a look-up table (MPHYSTBL=1) version for efficiency.

6. **Goddard microphysics** -
Includes additional equation for prediction of graupel. Suitable for cloud-resolving models. See Lin et al. (JCAM, 1983), Tao et al. (1989, 1993) for details.

7. **Reisner graupel** -
Based on mixed-phase scheme but adding graupel and ice number concentration prediction equations. Also suitable for cloud-resolving models.

8. **Schultz microphysics** -
A highly efficient and simplified scheme (based on Schultz 1995 with some further changes), designed for running fast and being easy to tune for real-time forecast systems. It contains ice and graupel/hail processes.

8.3.4 **Radiation Schemes (IFRAD)**

0. **None** -
No mean tendency applied to atmospheric temperature, unrealistic in long-term simulations.

1. **Simple cooling** -
Atmospheric cooling rate depends just on temperature. No cloud interaction or diurnal cycle.

0 or 1. **Surface radiation** -
This is used with the above two options. It provides diurnally varying shortwave and longwave flux at the surface for use in the ground energy budget. These fluxes are calculated based on atmospheric column-integrated water vapor and low/middle/high cloud fraction estimated from relative humidity.

2. **Cloud-radiation scheme** -
Sophisticated enough to account for longwave and shortwave interactions with explicit cloud and clear-air. As well as atmospheric temperature tendencies, this provides surface radiation fluxes. May be expensive but little memory requirement.

3. **CCM2 radiation scheme** -
Multiple spectral bands in shortwave and longwave, but cloud treated simply based on RH. Suitable for larger grid scales, and probably more accurate for long time integrations. Also provides radiative fluxes at surface. See Hack et al. (1993) for details.

4. **RRTM longwave scheme** -
This is combined with the cloud-radiation shortwave scheme when IFRAD=4 is chosen. This longwave scheme is a new highly accurate and efficient method provided by AER Inc. (Mlawer et al. 1997). It is the Rapid Radiative Transfer Model and uses a correlated-k model to represent the
effects of the detailed absorption spectrum taking into account water vapor, carbon dioxide and ozone. It is implemented in MM5 to also interact with the model cloud and precipitation fields in a similar way to IFRAD=2.

Illustration of Free Atmosphere Radiation Processes

- Longwave emission
- Shortwave absorption
- Reflection
- Scattering
- Surface emissivity
- Surface albedo
- Cloud
- Clear sky
8.3.5 Ground Temperature Schemes (ISOIL)

None - (ITGFLG=3)
No ground temperature prediction. Fixed surface temperature, not realistic.

0. Force/restore (Blackadar) scheme -
Single slab and fixed-temperature substrate. Slab temperature based on energy budget and depth assumed to represent depth of diurnal temperature variation (~ 10-20 cm).

1. Five-Layer Soil model -
Temperature predicted in 1, 2, 4, 8, 16 cm layers (approx.) with fixed substrate below using vertical diffusion equation. Thermal inertia same as force/restore scheme, but vertically resolves diurnal temperature variation allowing for more rapid response of surface temperature. See Dudhia (1996 MM5 workshop abstracts) for details. Cannot be used with Burk-Thompson PBL (IBLTYP=3).

2. OSU/Eta Land-Surface Model
The land-surface model is capable of predicting soil moisture and temperature in four layers (10, 30, 60 and 100 cm thick), as well as canopy moisture and water-equivalent snow depth. It also outputs surface and underground run-off accumulations. The LSM makes use of vegetation and soil type in handling evapotranspiration, and has effects such as soil conductivity and gravitational flux of moisture. In MM5 it may be called instead of the SLAB model in the MRF PBL, taking surface-layer exchange coefficients as input along with radiative forcing, and precipitation rate, and outputting the surface fluxes for the PBL scheme. This scheme uses a diagnostic equation to obtain a skin temperature, and the exchange coefficients have to allow for this by use of a
suitable molecular diffusivity layer to act as a resistance to heat transfer.

8.4 Interactions of Parameterizations

8.5 Four-Dimensional Data Assimilation (FDDA)

8.5.1 Introduction

FDDA is a method of running a full-physics model while incorporating observations. Thus the model equations assure a dynamical consistency while the observations keep the model close to the true conditions and make up for errors and gaps in the initial analysis and deficiencies in model physics. The MM5 model uses the Newtonian-relaxation or nudging technique.

8.5.2 FDDA Method

There are two distinct nudging methods. The model can use these individually or combined.

Analysis or Grid Nudging -

Newtonian relaxation terms are added to the prognostic equations for wind, temperature, and water vapor. These terms relax the model value towards a given analysis. The technique is imple-
mented by obtaining analyses on the model grid over the data assimilation period and these are fed to the model in its standard input format. The model linearly interpolates the analyses in time to determine the value towards which the model relaxes its solution. The user defines the time scale of the relaxation constants for each variable.

Station or Observational Nudging -
In situations where analysis-nudging is not practical, such as at high resolution or with asynoptic data, obs-nudging is a useful alternative. This method again uses relaxation terms, but the method is similar to objective analysis techniques where the relaxation term is based on the model error at observational stations. The relaxation is such as to reduce this error. Each observation has a radius of influence, a time window and a relaxation time scale to determine where, when and how much it affects the model solution. Typical model grid points may be within the radius of influence of several observations and their contributions are weighted according to distance. To implement this method an observation input file is required that chronologically lists the 3D positions and values of each observation in a specific format.

8.5.3 Uses of FDDA
Four-Dimensional Data Assimilation has three basic uses -

• Dynamic Initialization: Data assimilation by the above methods is applied during a pre-forecast time period for which additional observations or analyses exist. Then the nudging terms switch off as the forecast begins. This has two advantages over the standard static initialization, (i) It can make use of asynoptic data during the pre-forecast period and generally contains more observational information at the forecast start time, and (ii) There is a reduced spin-up or shock effect at the forecast start owing to the better balance of the initial model conditions.

• Dynamic Analysis: This is the same as dynamic initialization except that the intent is to produce a four-dimensionally consistent analysis taking into account dynamical balances that are provided by the model and observations that are introduced by nudging. This analysis may be used to initialize higher-resolution simulations or for kinematic studies such as chemical and tracer transports.

• Boundary Conditions: By using data assimilation on the coarse mesh and nesting with a finer mesh, the fine mesh is provided with superior boundary conditions compared to the standard linear interpolation of analyses, because the boundaries have a much higher time resolution of features passing through them into the fine mesh.

Note: For scientific case studies and forecasts the model should have no data assimilation terms as these represent non-physical terms in the equations.

8.5.4 Data used in FDDA
Analysis nudging -
When doing three-dimensional analysis nudging, no additional input data files are required. MM5 can use the same MMINPUT file or a copy of MMINPUT to MMINPUT2 file. If surface FDDA is desired, a user must set F4D = TRUE in the namelist of RAWINS job deck, which enables the job to create (typically) a 3-hourly surface analysis file to be used in MM5.
Station nudging -

There is no standard software available to create input data file for observational nudging. The input file is a binary file containing 9 real numbers per record and in order of increasing time. The READ statement in the model is the following:

```
READ (NVOL,END=111) TIMEOB,RIO,RJO,RKO,(VAROBS(IVAR),IVAR=1,5)
```

where NVOL is the input fortran unit number, and

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIMEOB:</td>
<td>Julian date in dddhh. Example: 16623.5 - Julian day 166 and hour 2330 UTC</td>
</tr>
<tr>
<td>RIO:</td>
<td>y-location - I dot-point location on coarse mesh (may be a fraction of a grid)</td>
</tr>
<tr>
<td>RJO:</td>
<td>x-location - J dot-point location on coarse mesh (may be a fraction of a grid)</td>
</tr>
<tr>
<td>RKO:</td>
<td>z-location - K half-σ level (must be on half σ levels)</td>
</tr>
<tr>
<td>IVAR(1):</td>
<td>u wind - in m/sec rotated to model grid</td>
</tr>
<tr>
<td>IVAR(2):</td>
<td>v wind - in m/sec rotated to model grid</td>
</tr>
<tr>
<td>IVAR(3):</td>
<td>temperature - in Kelvin</td>
</tr>
<tr>
<td>IVAR(4):</td>
<td>water vapor mixing ratio - in kg/kg</td>
</tr>
<tr>
<td>IVAR(5):</td>
<td>Pstar - in cb (only used in hydrostatic model)</td>
</tr>
</tbody>
</table>

A user may include more information at the end of a record which are not read by the model but can be used to identify the station and data type. The no-data value is 99999. If running the model in nonhydrostatic mode, 99999. can be used to fill up the Pstar spot.
8.6 How to run MM5

There are 2 steps to compiling and running the MM5 system.

- Choosing compilation options and compiling the code.
- Modifying the run-time options and executing the program.

8.6.1 Compiling MM5

- Edit the file “configure.user”
- Type ‘make’

(see 8.6.3 for running batch job on Cray.)

The user chooses those compilation options appropriate to his/her system by editing the “configure.user” file. This file is included in every Makefile used in compiling the model so it contains many rules, but the user need only concern with 4 things.

- Find the section of compilation options appropriate for your machine. Uncomment the RUNTIME_SYSTEM variable and the compiler options.
- Make sure that the general utilities required in a UNIX environment for compilation are available and appropriate. For example, there are many versions of the program “make” - if yours has special quirks and/or options, this would be the place to indicate them.
- Set model options in sections 5 and 6 of configure.user. These are used to set up domain sizes, 4DDA and physics option for (selective) compiling purposes.

When finished editing, just type ‘make’ to compile the code.

If you wish to compile the model on a PC with Linux OS,
- copy the configure.user.linux file to configure.user;
- type ‘make’

If you wish to compile and run the model on a distributed-memory machine (such as IBM SP2, Cray T3E, SGI Origin 2000 with MPI),
- obtain additional tar file, MPP.TAR.gz, gunzip and then untar the file in the MM5 top directory;
- edit the configure.user file, and select and uncomment the appropriate RUNTIME_SYSTEM and compiler flags;
- type ‘make mpp’ to make an executable.

More information is provided for this topic in README.MPP in the MM5 tar file, and on Web page: http://www.mmm.ucar.edu/mm5/mpp.html

8.6.2 Running MM5

- create the “mm5.deck” script by typing ‘make mm5.deck’ - need to set RUNTIME_SYSTEM correctly to get the right deck.
- edit the mm5.deck script to set appropriate namelist values
- run the “mm5.deck” script by typing ‘mm5.deck’.
Basic Run:
Need to set at least these namelist variables:
TIMAX, TISTEP, TAPFRQ, NESTIX, NESTJX, NESTI, NESTJ

Restart Run:
In addition to above namelist variables, set IFREST = .TRUE., and IXTIMR = restart time (can be found at the end of the previous run).

One-Way Run:
Should treat a one-way run in exact manner as if it is a basic run.

8.6.3 Running MM5 Batch Job on Cray

• If you want to work in batch mode, whether to compile and/or execute, get a copy of mm5.deck.cray from mesouser directory: ~mesouser/MM5V3 on ouray/paiute/chipeta. Or, you may get the deck once you obtain the MM5.TAR.gz file on your local machine. To do so, first unzip and untar the tar file, edit the configure.user file to define RUNTIME_SYSTEM=“CRAY”; then type ‘make mm5.deck’. This deck has an appearance of V1/V2 deck, and has the configure.user file inside the deck. This deck is designed to be used for both interactive and batch mode.

• If you would like to compile interactively on a Cray, you can either use the above deck, or use the Cray interactive deck, by setting the RUNTIME_SYSTEM=“CRAY_IA”, and followed by typing ‘make mm5.deck’. The mm5.deck generated this way has an appearance of other workstations decks.

• When you use the interactive deck to compile, you will still need to use the batch deck to submit a batch job for executing. Before you submit the batch job, remember to tar up your entire directory structure, and save it to some place (whether it is NCAR’s MSS, or your local archive). Your batch job needs to access this tar file (default name mm5exe.tar) for executing.

Note: The mmlif (namelist file) for running MM5 is now generated from both your configure.user file (section 6 of the configure.user) and mm5.deck.

8.7 Input to MM5

Files from INTERPF program

• Model initial condition file(s): MMINPUT_DOMAINx
• Lateral and lower boundary condition files for the coarsest domain:
  BDYOUT_DOMAIN1, LOWBDY_DOMAIN1

Files from MM5 program, if it is a restart run

• Model save file(s) from previous run: rename SAVE_DOMAINx to
8: MM5

RESTART_DOMAINx

Files from RAWINS, if running gridded 4DDA option with surface analysis

- FDDA surface analysis: SFCFDDA_DOMAINx

Files generated by user, if running observational nudging option

- FDDA 4D obs file(s): MM5OBS_DOMAINx

mmlif: a namelists file containing user-specified options.

LANDUSE.TBL: user-modifiable landuse characteristics (in ASCII)

Note that the workstation mm5.deck expects all input files (named as above) to be in the Run directory. See the mm5.deck for details.

8.8 Output from MM5

A number of files are written out during MM5 integration. These are

- history files (MMOUT_DOMAINx), if IFTAPE = 1, and the output frequency is set by TAPFRQ.
- restart files (SAVE_DOMAINx), if IFSAVE = .TRUE., and the output frequency is set by SAVFRQ.

Output from each domain will be written to different files. For example, domain 1’s history file is written to MMOUT_DOMAIN1, and its restart file to SAVE_DOMAIN1. Each output file contains data for all output times for that domain. On NCAR’s Crays, if a model output file size exceeds 6,000 Mb, split.deck from mesouser directory will split it into smaller files. If the restart files exceed 6,000 Mb the bsplit utility will split the binary file (cat can be used to re-join it).

For each time period the model history output includes:

- A general header record describing the model configuration
- A subheader describing the field following, and the field. This is repeated for all fields in a output.

3D forecast fields dimensioned by (IX, JX, KX or KX+1) for that domain include (note that the variables are NO LONGER coupled in Version 3):

<table>
<thead>
<tr>
<th></th>
<th>Field Description</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>U-wind (m/s)</td>
<td>dot</td>
</tr>
<tr>
<td>2</td>
<td>V-wind (m/s)</td>
<td>dot</td>
</tr>
<tr>
<td>3</td>
<td>Temperature (K)</td>
<td>cross</td>
</tr>
<tr>
<td>4</td>
<td>Water vapor mixing ratio (kg/kg) (if IMPHYS≥2)</td>
<td>cross</td>
</tr>
<tr>
<td>5</td>
<td>Cloud water mixing ratio (kg/kg) (if IMPHYS≥3)</td>
<td>cross</td>
</tr>
<tr>
<td>6</td>
<td>Rain water mixing ratio (kg/kg) (if IMPHYS≥3)</td>
<td>cross</td>
</tr>
<tr>
<td>7</td>
<td>Ice cloud mixing ratio (kg/kg)</td>
<td>cross</td>
</tr>
</tbody>
</table>
8: MM5

8. Snow mixing ratio (kg/kg) (if IMPHYS ≥ 5)
9. Graupel (kg/kg) (if IMPHYS ≥ 6)
10. Number concentration of ice (if IMPHYS 6)
11. Turbulent k.e. (J/kg) (if IBLTYP = 3, 4, 6)
12. Atmospheric radiation tendency (K/day) (if FRAD ≥ 2)
13. Vertical velocity (m/s)
14. Perturbation pressure (Pa)

2D forecast fields dimensioned (IX, JX) include:
1. Pstar (cb)
2. Ground temperature (K)
3. Accum. convective rainfall (cm)
4. Accum. nonconv. rainfall (cm)
5. PBL height (m)
6. PBL regime (category, 1-4)
7. Surface sensible heat flux (W/m^2)
8. Surface latent heat flux (W/m^2)
9. Frictional velocity (m/s)
10. Surface downward shortwave radiation (W/m^2)
11. Surface downward longwave radiation (W/m^2)
12. Soil temperature in a few layers (K) (if ISOIL = 1, 2)
13. Soil moisture in a few layers (m^3/m^3) (if ISOIL = 2)
14. Surface runoff (mm) (if ISOIL = 2)
15. Underground runoff (mm) (if ISOIL = 2)
16. Snow cover (variable if ISOIL = 2)
17. Water-equivalent snow depth (mm) (if ISOIL = 2)
18. Canopy moisture (m) (if ISOIL = 2)

2D constant fields dimensioned (IX, JX) include:
19. Terrain elevation (m)
20. Map scale factor
21. Map scale factor
22. Coriolis parameter (/s)
23. Substrate temperature (K)
24. Latitude (deg)
25. Longitude (deg)
26. Land-use category
27. Snow cover
28. Sea surface temperature (K)
29. Seaice (dimensionless) (if ISOIL = 2)
8.9 MM5 Files and Unit Numbers

The data for each domain is written to a separate file. MM5 accesses most files by referring to the fortran unit number. Unit number are assigned as follows:

Table 8.1 File names, fortran unit numbers, and their description for MM5.

<table>
<thead>
<tr>
<th>File name</th>
<th>Unit number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>mmlif</td>
<td>fort.10</td>
<td>Input, namelist file</td>
</tr>
<tr>
<td>LOWBDY_DOMAIN1</td>
<td>fort.8</td>
<td>Input, lower boundary file, contains substrate temp and SST</td>
</tr>
<tr>
<td>BDYOUT_DOMAIN1</td>
<td>fort.9</td>
<td>Input, lateral boundary file created by program INTERPF</td>
</tr>
<tr>
<td>LANDUSE.TBL</td>
<td>fort.19</td>
<td>Input, physical properties for landuse categories</td>
</tr>
<tr>
<td>MMINPUT_DOMAINx (TERRAIN_DOMAIN2..)</td>
<td>fort.11, 12, ... 19</td>
<td>Input, initial condition files created by program INTERPF (and NESTDOWN); or Terrain output files for nests</td>
</tr>
<tr>
<td>MMINPUT(2)_DOMAINx</td>
<td>fort.31, 32, ... 39</td>
<td>Input, 3D analysis nudging files (same as initial condition files)</td>
</tr>
<tr>
<td>SFCFDDA_DOMAINx</td>
<td>fort.71, 72, ... 79 (fort.81, 82, ... 89)</td>
<td>Input, surface analysis nudging files created by program RAWINS</td>
</tr>
<tr>
<td>MM5OBS_DOMAINx</td>
<td>fort.61,62, ... 69</td>
<td>Input, observation nudging files created by user’s own program</td>
</tr>
<tr>
<td>RESTART_DOMAINx</td>
<td>fort.91, 92 ... 99</td>
<td>Input, restart files (same as SAVE_DOMAINx files)</td>
</tr>
<tr>
<td>MMOOUT_DOMAINx</td>
<td>fort.41,42, ... 49</td>
<td>Output, MM5 model history files</td>
</tr>
<tr>
<td>SAVE_DOMAINx</td>
<td>fort.51, 52, ..., 59</td>
<td>Output, restart files</td>
</tr>
<tr>
<td>SHUTDO_DOMAINx</td>
<td>fort.61, 62, ..., 69</td>
<td>Output, shutdown restart files</td>
</tr>
</tbody>
</table>

8.10 Configure.user Variables

The ‘configure.user’ is the first file one needs to edit (if one is running Cray batch job, one would need to edit the mm5.deck only and these variables appear inside the deck). Except for the first variable, the rest are used for setting up model’s memory - these variables are referred to as pre-compilation variables. Sections 1, 4 and make rules will be explained in Chapter 9.
RUNTIME_SYSTEM  
computer system to run model on.

FDDAGD  
=1, for 4DDA grid analysis nudging; =0, no 4DDA.

FDDAOB  
=1, for 4DDA observation nudging; =0, no obs 4DDA.

MAXNES  
maximum number of domains in simulation. Note though, there are only 4 default nest levels.

MIX,MJX,MKX  
maximum number of grid points in I, J, and K.

IMPHYS  
options for explicit schemes:
=1, dry;
=2, removal of super-saturation;
=3, warm rain (Hsie);
=4, simple ice (Dudhia);
=5, mixed phase (Reisner);
=6, mixed phase with graupel (Goddard);
=7, mixed phase with graupel (Reisner);
=8, mixed phase with graupel (Schultz)

MPHYSTBL  
=1, use look-up table version of explicit scheme options 4 and 5;  
=0, not using look-up table version.

ICUPA  
options for cumulus parameterization schemes:
=1, none;
=2, Anthes-Kuo;
=3, Grell;
=4, Arakawa-Schubert;
=5, Fritsch-Chappell;
=6, Kain-Fritsch;
=7, Betts-Miller.

IBLTYP  
options for planetary boundary layer schemes:
=0, no PBL;
=1, bulk PBL;
=2, Blackadar PBL;
=3, Burk-Thompson PBL;
=4, Eta PBL;
=5, MRF PBL;
=6, Gayno-Seaman PBL

FRAD  
options for atmospheric radiation schemes:
=0, none;
=1, simple cooling;
=2, cloud (Dudhia) (require IMPHYS \geq 3);
=3, CCM2;
=4, RRTM longwave scheme.
ISOIL         =1, use the multi-layer soil model (require IBLTYP=2, 4, 5, 6);
             =0, no soil model;
             =2, OSU LSM model (requires IBLTYP=5).

ISHALLO      =1, use shallow convective scheme;
             =0, no.

8.11 Script Variables for Cray Batch Deck:

NCPUS        number of processors to use (if NCPUS>1, use with -O task1 in compiler option).

ExpName      experiment name used in setting MSS pathname for output.

InName       input MSS pathname.

RetPd        mass store retention period (days).

compile      =yes, compile the mm5 code;
              =no, expect an existing executable.

execute      =yes, execute the model;
              =no, compile the code only.

UseMySource  =yes, use your own source code;
              =no, use mesouser version of the source code.

CaseName     MSS pathname for this run.

STARTsw      = NoReStart: start model run at hour zero (initialize).
              = ReStart: restart model run.

FDDAsw       = NoFDDA, no FDDA input files,
              = Anly, gridded FDDA input files,
              = Obs, obsFDDA input files,
              = Both, gridded and obs FDDA input files.

InIEEE       = no: input files are not in IEEE format;
              = yes: input files are in IEEE format.

IEEEType     = 32/64: whether the input files are in 32- or 64-bit IEEE.

InBdy        MSS name of lateral boundary file.

InLow        MSS name for lower boundary condition file.

InMM         MSS name(s) of model input files.

InRst        MSS name(s) of model restart files.

In4DSfc      MSS name of surface analysis used for 4DDA.
In4DObs  MSS name of fdda obs files.
Host    = username@host.domain:/usr/tmp/username,
        host computer to rcp user’s mods.
OutMM   MSS name for output.

8.12 Namelist Variables

A namelist file, called mmlif, is created when mm5.deck is executed. In MM5, this file is created partially from the configure.user file, and partially from mm5.deck.

8.12.1 OPARAM

TIMAX  = forecast length in minutes.
TISTEP = time step in seconds for the coarsest domain (recommend 3*dx(km)).
IFREST =TRUE, for restart, =FALSE, for initial run.
IXTIMR  = integer time in minutes for restart.
IFSAVE  =TRUE, if saving data for restart, = FALSE, for no restart output.
SVLAST  = TRUE, if only saving the last time; = FALSE, save multiple times.
SAVFRQ  = frequency of restart output in minutes.
IFTAPE  = 1, for model output; =0, no model output.
TAPFRQ  = frequency of model history file output in minutes.
BUFFRQ  = how frequency to split model output files in minutes (ignored if < TAPFRQ).
INCTAP  = multipliers of TAPFRQ for outputting.
IFSKIP  = TRUE, skip input files to start the model - DO NOT use this when restart.
CDATEST = DATE (yyyy-mm-dd_hh:mm:ss) of the start file
IFPRT   = 1, for printed output fields; = 0, for no printed output fields
PRTFRQ  = frequency of printed output fields in minutes
MASCHK  = integer frequency in number of time steps for budget/rainfall prints
          (coarsest mesh)

8.12.2 LPARAM

1) Defined in mm5.deck:

RADFRQ  = frequency in minutes of radiation calculations
IMVDIF
= 1, for moist vertical diffusion in clouds (requires IMPHYS>2, and IBLTYP=2 or 5),
= 0, vertical diffusion is dry

IVQADV
= 0, vertical moisture advection uses log interpolation (old method),
= 1, vertical moisture advection uses linear interpolation (affects all moisture variables)

IVTADV
= 0, vertical temperature advection uses log interpolation (old method),
= 1, vertical temperature advection uses linear interpolation

ITHADV
= 0, temperature advection and adiabatic term use temperature (old method),
= 1, temperature advection and adiabatic term use potential temperature

ITPDIF
= 1, for diffusion using perturbation temperature in NH model;
= 0, not using this function (new in V2)

ICOR3D
= 1, for full 3D Coriolis force (requires INHYD=1),
= 0, for traditional approximation.

IFUPR
= 1, for upper radiative boundary condition (NH run only).
= 0, rigid upper boundary in nonhydrostatic runs.

IFDRY
= 1, for fake dry run with no latent heating release (requires IMPHYS>1, and ICUPA=1)

ICUSTB
= 1, stability check in Anthes-Kuo convective scheme;
= 0, do not use stability check in Anthes-Kuo scheme.

IBOUDY
Boundary condition options:
= 0, fixed,
= 2, time-dependent (recommend all 2-way nests use this option),
= 3, relaxation inflow/outflow (NH run) or inflow/outflow (hydrostatic run),

IFSNOW
= 1, snow cover effects (requires input SNOWC field from DATAGRID, and ITGFLG=1

ISFFLX
= 1, compute surface heat and moisture fluxes; =0, no fluxes.

ITGFLG
= 1, ground temperature predicted;
= 3, constant ground temperature.

ISFPAR
= 1, use 13 land-use categories;
= 0, use only 2 (land/water) categories.

ICLOUD
= 1, consider cloud effects on surface radiation when FRAD=0,1 ; consider both surface and atmospheric radiation when FRAD=2 (requires ITGFLG=1, ISFFLX=1);
\[ \text{IEVAP} = \begin{cases} 1, & \text{normal evaporative cooling;} \\ 0, & \text{no evaporative effects;} \\ -1, & \text{no precip evaporative cooling, (for IMPHYS=3,4, and 5).} \end{cases} \]

2) Defined in `configure.user`, or internally produced:

- `IFRAD` see ‘Configure.user variables’
- `ICUPA` see ‘Configure.user variables’
- `IBLTYP` see ‘Configure.user variables’
- `ISHALLO` see ‘Configure.user variables’
- `ISOIL` see ‘Configure.user variables’

### 8.12.3 NPARAM

- `LEVIDN` = level of nest for each domain (0 for domain 1)
- `NUMNC` = id number of parent domain for each domain (1 for domain 1)
- `NESTIX` = I-dimension of each domain.
- `NESTJX` = J-dimension of each domain.
- `NESTI` = south-west corner point I for each domain.
- `NESTJ` = south-west corner point J for each domain.
- `XSTNES` = starting time in minutes for each domain.
- `XENNES` = ending time in minutes for each domain.
- `IOVERW` = 1, for initializing a nest from the nest input file, usually at model starting time;
  = 0, for interpolating to a nest from parent mesh, usually during model integration;
  = 2, for initializing domain with high resolution terrain, usually during model integration.
- `IACTIV` = 1, if this domain is active when restart;
  = 0, if this domain is inactive.
- `IMOVE` = 0, if domain does not move; =1, if domain will move.
- `IMOVCO` = number of first move (always 1 at beginning, may change for restarts).
- `MOVEI` = increment in I (parent domain grids) of this move for this domain.
- `MOVEJ` = increment in J (parent domain grids) of this move for this domain.
- `IMOVET` = time in minutes of this move for this domain (relative to beginning of the coarse mesh run).
**IFEED**

Feedback from nest to coarse mesh in 2-way nests:
- 0, no feedback;
- 1, 9-point weighted average;
- 2, 1-point feedback, with no smoothing;
- 3, 1-point feedback, with smoother/desmoother (recommended);
- 4, 1-point feedback, with heavy smoothing

Note: the default number of moves is 10.

### 8.12.4 PPARAM

- **ZZLND** = roughness length over land (m) (if ISFPAR=0)
- **ZZWTR** = roughness length over water (m) (if ISFPAR=0)
- **ALBLND** = albedo over land (if ISFPAR=0)
- **THILND** = thermal inertia of land (cal·cm⁻² K⁻¹ s⁻⁰·⁵, if ISFPAR=0)
- **XMAVA** = moisture availability over land (if ISFPAR=0)
- **CONF** = non-convective precip saturation criterion (fraction ≤ 1 for IMPHYS=1)

### 8.12.5 FPARAM

- **FDASTA** (MAXSES); time (min) for initiation of FDDA
- **FDAEND** (MAXSES); time (min) for termination of FDDA
- **I4D** (MAXSES, 2); will FDDA analysis nudging be employed, (0=no; 1=yes)
- **DIFTIM** (MAXNES, 2); time (min) between input analyses for analysis nudging
- **I4WIND** (MAXSES, 2); will the wind field be nudged from analyses, (0=no; 1=yes)
- **GV** (MAXSES, 2); analysis-nudging coefficient (s⁻¹) for wind
- **ITEMP** (MAXSES, 2); will the temperature be nudged from analyses, (0=no; 1=yes)
- **GT** (MAXSES, 2); analysis-nudging coefficient (s⁻¹) for temperature
- **IMOIS** (MAXSES, 2); will the mixing ratio be nudged from analyses, (0=no; 1=yes)
- **GQ** (MAXSES, 2); analysis-nudging coefficient (s⁻¹) for mixing ratio
- **I4ROT** (MAXSES); will vorticity be nudged from analyses, (0=no; 1=yes)
- **GR** (MAXSES, 2); analysis-nudging coefficient (m² s⁻¹) for vorticity
- **INONBL** (MAXSES, 4); will PBL fields be nudged from 3-D analyses when not using surface-analysis nudging within PBL. (0=yes; 1=exclude certain variables depending on integer value of second index)
- **RINBLW** radius of influence (km) for surface-analysis nudging where the horizontal
weighting function depends on surface data density.

**NPFG**
coarse-grid time-step frequency for select diagnostic print of analysis nudging.

**I4DI**
(MAXSES); will FDDA observation nudging be employed, (0=no; 1=yes).

**ISWIND**
(MAXSES); will the wind field be nudged from observations, (0=no; 1=yes).

**GIV**
(MAXSES); observation-nudging coefficient (s\(^{-1}\)) for wind.

**ISTEMP**
(MAXSES); will the temperature be nudged from observations, (0=no; 1=yes).

**GIT**
(MAXSES); observation-nudging coefficient (s\(^{-1}\)) for temperature.

**ISMOIS**
(MAXSES); will the mixing ratio be nudged from observations, (0=no; 1=yes).

**GIQ**
(MAXSES); observation-nudging coefficient (s\(^{-1}\)) for mixing ratio.

**RINXY**
default horizontal radius of influence (km) for distance-weighted nudging corrections (for observation nudging).

**RINSIG**
vertical radius of influence (on sigma) for distance-weighted nudging corrections (for observation nudging).

**TWINDO**
(time window)/2 (min) over which an observation will be used for nudging.

**NPFI**
coarse-grid time-step frequency for select diagnostic print of observation nudging.

**IONF**
observation-nudging frequency in coarse grid time steps for observation-nudging calculations.

**IDYNIN**
for dynamic initialization using a ramp-down function to gradually turn off the FDDA before the pure forecast (1=yes, 0=no).

**DTRAMP**
the time period in minutes over which the nudging (obs nudging and analysis nudging) is ramped down from one to zero. Set dtramp negative if FDDA is to be ramped down BEFORE the end-of-data time (DATEND), and positive if the FDDA ramp-down period extends beyond the end-of-data time, g calculations.

### 8.13 Some Common Errors Associated with MM5 Failure

When an MM5 job is completed, always check for at least the following:

- The “STOP 99999” print statement indicates that MM5 completed without crashing.

- When running a Cray job, check to be sure that the `mswrite` commands were all completed successfully by the shell, and that the files were written to the pathnames you expected.

- Check the top of “mm5.print.out” file to see if all domains are correctly initiated if running a multiple-domain job, and if the physics options are correctly specified.

If an MM5 job has failed, check for some of the common problems:

- If your model stops immediately after it prints out ‘NON-HYDROSTATIC RUN’ with an
‘Segmentation fault’ or sometimes ‘Bus error’, it is a good indication that the model is not getting enough memory to run. On most machine, typing ‘unlimit’ before you run the model will be the solution.

- “Read past end-of-file”: This is usually followed by a fortran unit number. Check this unit number with Table 8.1 to find out which file MM5 has problem with. Check all the MSREAD statements in the printout to be sure that files were read properly from the MSS. Also check to make sure that the file sizes are not zero. Double-check experiment names, MSS pathnames.

- “CPU limit exceeded”: Increase the amount of time requested in the QSUB statements when running the job on a Cray.

- “Not enough space”: Increase the amount of memory requested in the QSUB statements when running on a Cray.

- “Unrecognized namelist variable”: This usually means there are typos in the namelist.

- Unmatched physics option: for instance, the following should appear in the output:

  STOP SEE ERRORS IN PRINT-OUT
  If one browses through the output, one may find things like:
  ERROR: IFRAD=2 REQUIRES IRDDIM=1 AND IMPHYS>3
  which tells a user what a user needs to do to correct the problem.

- Uncompiled options:

  STOP SEE ERRORS IN PRINT-OUT
  If one browses through the output, one may find things like:

  ERROR: IFRAD=2, OPTION NOT COMPILED
  which tells a user the option you choose has not been compiled.

- When restarting a job, do not re-compile. If you do re-compile, do not change anything in the configure.user file.

- If the job stopped and there is a long list of “CFL>1...”, it usually means the time step (TISTEP in namelist) is too big. Shorten the TISTEP and re-submit.

- If doing a multi-domain run, please check these namelist variables carefully:

  LEVIDN = 0,1,1,1,1,1,1,1,1,1, ; level of nest for each domain
  NUMNC = 1,1,1,1,1,1,1,1,1,1, ; ID of mother domain for each nest
  They should match what one had in INTERP/GRIN deck.
8.14 MM5 tar File

The mm5.tar file contains the following files and directories:

- **CHANGES**
  Description of changes to the MM5 program

- **Makefile**
  Makefile to create MM5 executable

- **README**
  General information about the MM5 directory and how to run MM5

- **README.MPP**
  General information on how to compile and run on DM machines

- **Diff/**
  Diff files for each new release

- **Run/**
  Where MM5 runs

- **Templates/**
  MM5 job decks for different machines

- **Util/**
  Utility programs for cpp

- **configure.user**
  Make rules and model configuration

- **configure.user.linux**
  Make rules and model configuration for PC running Linux OS

- **domain/**
- **dynamics/**
- **fdda/**
- **include/**
- **memory/**
- **physics/**
- **pick/**

The file **README** contains basic instructions on how to compile and run the model.

The model is executed in the directory **Run**.

The bug fixes and changes to the source code and tar file are provided in directory **ReleaseNotes**, and described in file **CHANGES**.

All FORTRAN files are in lower-case directories separated according to their functions. See the chart at the end of this chapter for a complete list of FORTRAN files.

When ‘make code’ command is executed, all .F and .f files selected for compiling are copied into the **pick/** directory. A single cat command will enable a user to generate a source listing (see the **README** file in directory **pick/**).
8.15 Configure.user

# Sections
# 1. System Variables
# 3. Fortran options
# 3a. Cray (YMP, J90)
#       Note: set RUNTIME_SYSTEM = "CRAY_IA" for Cray interactive job
# 3b. IRIX.6.X (SGI_Origin, SGI_R10000, SGI_R8000 which support OpenMP)
# 3b2. IRIX.6.X (SGI_Origin, SGI_R10000, SGI_R8000)
# 3c. IRIX.5.2/5.3, IRIX.6.X (SGI_R4000/SGI_R4400/SGI_R5000)
#       Note: set RUNTIME_SYSTEM = "SGI_R4000" for SGI_R4400/SGI_R5000
# 3d. SUN Fortran (solaris, SPARC20/SPARC64)
# 3e. DEC_ALPHA (OSF/1)
# 3e2. DEC_ALPHA (4100/8400; use OpenMP parallel directives)
# 3f. IBM (AIX)
# 3f2. IBM, OpenMP (AIX)
# 3g. HP (UX)
# 3h. HP (SPP-UX) for HP Exemplar S/X-Class Systems
# 4. General commands
# 5. Options for making "/include/parame.incl"
# 6. Physics Options (memory related)
# 7. MPP Options (Set no options in section 3)
# 7a. IBM SP2
# 7b. Cray T3E
# 7c. SGI Origin 2000
# 7d. HP Exemplar
# 7e. DEC ALPHA/mpi
# 7f. Fujitsu VPP
# 7g. Network of Linux PCs with MPI

# 1. System Variables
SHELL = /bin/sh
.SUFFIXES: .F .i .o .f .c

# 3. Fortran options
# Uncomment the ones you need, including RUNTIME_SYSTEM
LIBINCLUDE = $(DEVTOP)/include

# 3a. Cray
#       Note: - imsl library is only needed if running Arakawa-Schubert cumulus scheme;
#       and the location of the library may be different on non-NCAR Crays.
#       - if you are using the new program environment on Cray, should set
#         CPP = /opt/ctl/bin/cpp
#       - select the right compilation option for Cray - you may use
#         f90 option on palute
#       - -x omp is needed for f90 compiler version 3.0.2.6 and above.
#         Check man page.

#RUNTIME_SYSTEM = "CRAY_IA"
FC = f90
FCFLAGS = -D$(RUNTIME_SYSTEM) -I$(LIBINCLUDE) -O task1 -x omp
CFLAGS =
CPP = /opt/ctl/bin/cpp
CPPFLAGS = -I$(LIBINCLUDE) -C -P
LDOPTIONS =
LOCAL_LIBRARIES = -L /usr/local/lib -l imsl
MAKE = make -i -r

# 3b. IRIX.6.X (SGI_Origin, SGI_R10000, SGI_R8000 which support OpenMP)
# Use OpenMP directives for multi-processor runs.
#       - set RUNTIME_SYSTEM = SGI_Origin
#        - works with 7.2.1 and above compiler
#        - select appropriate XLOCAL0 macro for loader option
#
#    - For parallel execution of MM5 set the following environment variables:
# setenv OMP_NUM_THREADS <number_of_processors>
# setenv _DSM_PLACEMENT ROUND_ROBIN
#    - For parallel execution on a processor set without contention:
# setenv _DSM_WAIT SPIN
# setenv OMP_DYNAMIC FALSE
# setenv MPC_GANG OFF
#    - For parallel execution on a contented set of processors:
# setenv _DSM_WAIT YEILD
# setenv OMP_DYNAMIC TRUE
# setenv MPC_GANG OFF
#   3b2. IRIX.6.X (SGI_Origin, SGI_R10000, SGI_R8000)
# Use SGI directives for multi-processor runs.
#    - set RUNTIME_SYSTEM = SGI_R8000
#    - use the appropriate LDOPTIONS if compiling Burk-Thompson PBL,
#      Gayno-Seaman PBL, or OSU land-surface module
#    - use 7.0 and above compiler
#    - do not use -lfastm for R10000 and Origin series for compiler
# versions 7.0 and 7.1, unless patches are installed. For more
# information please see MM5 Web page:
#   http://www.mmm.ucar.edu/mm5/mm5v2-sgi.html
### Burk-Thompson (IBLTYP=3) option mp directives

LDOPTIONS = -n32 -mips4 -mp -Wl,-Xlocal,bt1_,-Xlocal,blk1_,-Xlocal,blk2_

### Gayno-Seaman (IBLTYP=6) option mp directives

LDOPTIONS = -n32 -mips4 -mp -Wl,-Xlocal,fog1d_,-Xlocal,surface1_,-Xlocal,surface2_,-Xlocal,surface3_,-Xlocal,comsurfslab_

### OSU LSM (ISOIL=2) option mp directives

LDOPTIONS = -n32 -mips4 -mp -Wl,-Xlocal,rite_,-Xlocal,abci_

LOCAL_LIBRARIES = -lfastm

MAKE = make -i -r

# 3c. IRIX.6.X (SGI_R4400/SGI_R4000/SGI_R5000)

RUNTIME_SYSTEM = "SGI_R4000"

FC = f77

FCFLAGS = -I$(LIBINCLUDE) -mips2 -32 -O2 -Nn30000 -Olimit 1500

CFLAGS =

CPP = /usr/lib/cpp

CPPFLAGS = -I$(LIBINCLUDE) -C -P

LDOPTIONS =

LOCAL_LIBRARIES = -lfastm

MAKE = make -i -r

# 3d. SUN (solaris,SPARC20/SPARC64)

RUNTIME_SYSTEM = "SUN"

FC = f77

FCFLAGS = -fast -O2 -I$(LIBINCLUDE)

CFLAGS =

CPP = /usr/lib/cpp

CPPFLAGS = -I$(LIBINCLUDE) -c -P

LDOPTIONS =

LOCAL_LIBRARIES =

MAKE = make -i -r

# 3e. DEC_ALPHA (OSF/1)

RUNTIME_SYSTEM = "DEC_ALPHA"

FC = f77

FCFLAGS = -cpp -D$(RUNTIME_SYSTEM) -I$(LIBINCLUDE) -c -O4 -Olimit 2000 -automatic -fpe0 -align dcommons -align records -warn nounreachable -convert big_endian

CFLAGS =

CPP = cpp

CPPFLAGS = -I$(LIBINCLUDE) -c -P

LDOPTIONS = -math_library accurate

LOCAL_LIBRARIES =

MAKE = make -i -r

# 3e2. DEC_ALPHA (4100/8400 Series)

Use OpenMP directives for multi-processor runs.

RUNTIME_SYSTEM = "DEC_ALPHA"

FC = f90

FCFLAGS = -omp -cpp -D$(RUNTIME_SYSTEM) -I$(LIBINCLUDE) -c -O4 -Olimit 2000 -automatic -fpe0 -align dcommons -align records -warn nounreachable -convert big_endian

CFLAGS =

CPP = cpp

CPPFLAGS = -I$(LIBINCLUDE) -c -P

LDOPTIONS = -omp -math_library accurate

LOCAL_LIBRARIES =

MAKE = make -i -r

# 3f. IBM (AIX)
#RUNTIME_SYSTEM = "IBM"
#FC = xlf
#FCFLAGS = -I$(LIBINCLUDE) -O3 -qarch=auto -qmaxmem=-1
#CPP = /usr/lib/cpp
#CFLAGS =
#CPPFLAGS = -I$(LIBINCLUDE) -C -P -Dr6000
#LDOPTIONS = -qmaxmem=-1 -O3 -qarch=auto
#LOCAL_LIBRARIES = -lmass
#MAKE = make -i

# 3f2. IBM (AIX)
#   - Depending on problem size and machine memory size, the settings
#     of maxstack and maxdata may need to be modified.
#   - If the newer thread-safe mass library is available, add
#     the -mass_r option to LOCAL_LIBRARIES.
#--------------------------------------------------------------------------------
#RUNTIME_SYSTEM = "IBM"
#FC = xlf_r
#FCFLAGS = -I$(LIBINCLUDE) -O3 -qarch=auto -qmaxmem=-1 -qsmp=noauto -qnosave -qstrict
#CPP = /usr/lib/cpp
#CFLAGS =
#CPPFLAGS = -I$(LIBINCLUDE) -C -P -Drs6000
#LDOPTIONS = -qmaxmem=-1 -O3 -qarch=auto -bmaxstack:512000000 -bmax-data:5120000
#LOCAL_LIBRARIES = -lxlsmp -lmass_r
#LOCAL_LIBRARIES = -lxlsmp
#MAKE = make -i

# 3g. HP (UX)
#--------------------------------------------------------------------------------
#RUNTIME_SYSTEM = "HP"
#FC = f77
#FCFLAGS = -I$(LIBINCLUDE) -O
#CPP = /usr/lib/cpp
#CFLAGS =
#CPPFLAGS = -I$(LIBINCLUDE) -C -P
#LDOPTIONS =
#LOCAL_LIBRARIES =
#MAKE = make -i -r

# 3h. HP-SPP (SPP-UX), and HP-SPP_IA
#--------------------------------------------------------------------------------
#RUNTIME_SYSTEM = "HP-SPP"
#FC = f77
#PA8K = +DA2.0N +DS2.0a
#ARCH = $(PA8K)
#PROFILE =
#INLINE = +Olimit +Oinline=_saxpy,vadv,hadv,sinty,sintx,slab,diffut
#PARALLEL = +O3 +Oparallel +Onofail_safe +Onoautopar +Onodysel
#
## Use the following FCFLAGS to build single-threaded executable
## FCFLAGS = $(PROFILE) $(ARCH) -I$(LIBINCLUDE) +O3 +Oaggressive \
## +Olibcalls $(INLINE)
#
## Use the following FCFLAGS to build a parallel executable
## FCFLAGS = $(PROFILE) $(ARCH) -I$(LIBINCLUDE) $(PARALLEL) \
## +O3 +Oaggressive +Olibcalls $(INLINE)
#
#CPP = /usr/lib/cpp
#CFLAGS = $(PROFILE) -Aa
#CPPFLAGS = $(FCFLAGS) -C -P -Dr6000
#LDOPTIONS = $(FCFLAGS) -Wl,-archive_shared -Wl,+FPD
#LOCAL_LIBRARIES = -Wl,/usr/lib/pa1.1/libm.a
#MAKE = gmake -j 4 -i -r
# General commands

AR = ar ru
RM = rm -f
RM_CMD = \$(RM) *.CKP *.ln *.BAK *.bak *.o *.i core errs ,* ~ *.a \.emacs_* tags TAGS make.log MakeOut *.f !
GREP = grep -s
CC = cc

# Options for making ./include/parame.incl

FDDAGD (integer) - "1" -> FDDA gridded run
FDDAGD = 0

FDDAOBS (integer) - "1" -> FDDA obs run
FDDAOBS = 0

MAXNES (integer) - Max Number of Domains in simulation
MAXNES = 2

MIX, MJX (integer) - Maximum Dimensions of any Domain
MIX = 49
MJX = 52

MKX (integer) - Number of half sigma levels in model
MKX = 23

# Physics Options

IMPHYS - for explicit moisture schemes (array,integer)
IMPHYS = "4,4,1,1,1,1,1,1,1,1"

MPHYSTBL = 0

ICUPA - for cumulus schemes (array,integer)
ICUPA = "3,3,1,1,1,1,1,1,1,1"

IBLTYP - for planetary boundary layer (array,integer)
IBLTYP = "5,5,2,0,0,0,0,0,0,0"

FRAD - for atmospheric radiation (integer)
FRAD = "2,0,0,0,0"

ISOIL - for multi-layer soil temperature model (integer)
ISOIL = 0
# 2=OSU land-surface scheme (IBLTYP=5)
ISOIL = 1
#
# ISHALLO (array, integer) - Shallow Convection Option
# 1=shallow convection, 0=No shallow convection
ISHALLO = "0, 0, 0, 0, 0, 0, 0, 0, 0, 0"
#-------------------------------------------------------------
# 7. MPP options
#
# For general information and updated "helpdesk" information see
# http://www.mmm.ucar.edu/mmm5/mpp
# http://www.mmm.ucar.edu/mmm5/mpp/helpdesk
#-------------------------------------------------------------
# Presently, of the MPP platforms only the "sp2"
# is supplied with the "make deck" capability.
#
# MPP Software Layer
MPP_LAYER=RSL
#MPP_LAYER=NNTSMS
#
# PROCMIN_NS - minimum number of processors allowed in N/S dim
#PROCMIN_NS = 1
#
# PROCMIN_EW - minimum number of processors allowed in E/W dim
#PROCMIN_EW = 1
#
# ASSUME_HOMOGENEOUS_ENVIRONMENT - on a machine with a heterogeneous
# mix of processors (different speeds) setting this compile time
# constant to 0 (zero) allows the program to detect the speed of each
# processor at the beginning of a run and then to attempt to come up with
# an optimal (static) mapping. Set this to 0 for a heterogeneous
# mix of processors, set it to 1 for a homogeneous mix. Unless you
# are certain you have a heterogeneous mix of processors, leave this
# set to 1. Currently, this option is ignored on platforms other
# than the IBM SP.
#ASSUME_HOMOGENEOUS_ENVIRONMENT = 1
#
#-------------------------------------------------------------
# 7a. IBM SP2
# type 'make mpp' for the SP2
#-------------------------------------------------------------
#RUNTIME_SYSTEM = "sp2"
#MPP_TARGET=$(RUNTIME_SYSTEM)
#MFC = xlf
#MCC = mpcc
#MLD = mpxlf
#FCFLAGS = -O3 -qstrict -qarch=auto -qhsflt
#LDOPTIONS =
#LOCAL_LIBRARIES = -lmass
#LOCAL_LIBRARIES = -lessl
#MAKE = make -i -r
#AWK = awk
#SED = sed
#CAT = cat
#CUT = cut
#EXPAND = expand
#M4 = m4
#CPP = /lib/cpp -C -P
#CPPFLAGS = -D_MPI -Drs6000
#CFLAGS = -DNOUNDERSCORE -D_MPI
### 7a.1 IBM SP with Silver or Winterhawk nodes
- You must compile with XLF or MPXLF version 6.1 or greater.
- Check with your system admin before linking to lessl or lmass.
- Note for running on blue.llnl.gov:
  - newmpxlf_r is LLNL specific wrapper around HPF 6.1 w/ HPF off.
  - If the newer thread-safe mass library is available, add
    the -lmass_r option to LOCAL_LIBRARIES.
- When MPP builds, it will use a copy of the file in MPP/RSL/Makefile.RSL.sp2
  which invokes the -qstrict option for the exmois routines.
- The -bmaxdata:0x70000000 flag on LDOPTIONS was suggested by
  Katja Stokely, the IBM Applications Analyst at NCAR

```bash
#ARCH_OBJS = milliclock.o
#IWORDSIZE = 4
#RWORDSIZE = 4
#LWORDSIZE = 4
#RUNTIME_SYSTEM = "sp2"
#MPP_TARGET=$(RUNTIME_SYSTEM)
## On llnl.blue.gov, (3/99)
##MFC = time newmpxlf_r
##MCC = mpcc_r
##MLD = newmpxlf_r
## On systems with R6.1 or greater of IBM Fortran.
#MFC = time mpxlf_r
#MCC = mpcc_r
#MLD = mpxlf_r
#FCFLAGS = -O3 -qarch=auto -qzerosize -qsmp=noauto, schedule=static -qnosave -qmaxmem=-1
#LDOPTIONS = -qsmp=noauto, schedule=static -bmaxdata:0x70000000
##LOCAL_LIBRARIES = -lmass_r
##LOCAL_LIBRARIES = -lessl
#LOCAL_LIBRARIES =
#MAKE = make -i -r
#AWK = awk
#SED = sed
#CAT = cat
#CUT = cut
#EXPAND = expand
#M4 = m4
#CPP = /lib/cpp -C -P
#CPPFLAGS = -DMPI -Drs6000
#CFLAGS = -DNOUNDERSCORE -DMPI
#ARCH_OBJS = milliclock.o
#IWORDSIZE = 4
#RWORDSIZE = 4
#LWORDSIZE = 4
#RUNTIME_SYSTEM = "t3e"
#MPP_TARGET=$(RUNTIME_SYSTEM)
#MFC = f90
#MCC = cc
#MLD = $(MFC)
#FCFLAGS = -g
#FCFLAGS = -O2
#LDOPTIONS =
#LOCAL_LIBRARIES =
#MAKE = make -i -r
#AWK = awk
#SED = sed
#CAT = cat
#CUT = cut
```

---

### 7b. T3E

```bash
#ARCH_OBJS = milliclock.o
#IWORDSIZE = 4
#RWORDSIZE = 4
#LWORDSIZE = 4
#RUNTIME_SYSTEM = "t3e"
#MPP_TARGET=$(RUNTIME_SYSTEM)
#MFC = f90
#MCC = cc
#MLD = $(MFC)
#FCFLAGS = -g
#FCFLAGS = -O2
#LDOPTIONS =
#LOCAL_LIBRARIES =
#MAKE = make -i -r
#AWK = awk
#SED = sed
#CAT = cat
#CUT = cut
```
#EXPAND = expand
#M4 = m4
#CPP = /opt/ctl/bin/cpp -C -P
#CPPFLAGS = -DMPI -DT3E
#CFLAGS = -DNOUNDERSCORE -Dt3e -DT3E -DMPI
#ARCH_OBJS = error_dupt3d.o t3etraps.o set_to_nan.o milliclock.o
#IWORDSIZE = 8
#RWORDSIZE = 8
#LWORDSIZE = 8

# 7c. Origin 2000
# Note that the MPP version of MM5 is not supported for compilation under
# the "modules" environment. To see if you are using modules to control
# compiler versions on your machine, type "module list".

#RUNTIME_SYSTEM = "o2k"
#MPP_TARGET=$(RUNTIME_SYSTEM)
#MFC = f77 -n32 -mips4 -w
#MCC = cc -n32 -mips4 -w
#MLD = f77 -n32 -mips4
#FCFLAGS = -g
#FCFLAGS = -O3 -OPT:roundoff=3:IEEE_arithmetic=3 -OPT:fold_arith_limit=2001
#LDOPTIONS =
#LOCAL_LIBRARIES = -llfastm /usr/lib32/libmpi.so
#MAKE = make -i -r
#AWK = awk
#SED = sed
#CAT = cat
#CUT = cut
#EXPAND = expand
#M4 = m4
#CPP = /lib/cpp -C -P
#CPPFLAGS = -DMPI -DO2K
#CFLAGS = -DNOUNDERSCORE -DMPI
#ARCH_OBJS = milliclock.o
#IWORDSIZE = 4
#RWORDSIZE = 4
#LWORDSIZE = 4

# 7d. HP Exemplar

#RUNTIME_SYSTEM = "hp"
#MPP_TARGET=$(RUNTIME_SYSTEM)
#MFC = f77
#MCC = mpicc
#MLD = mpif77
#FCFLAGS = +DA2.0N +DS2.0a -g
#FCFLAGS = +DA2.0N +DS2.0a +O3
#LDOPTIONS =
#MAKE = make -i -r
#AWK = awk
#SED = sed
#CAT = cat
#CUT = cut
#EXPAND = expand
#M4 = m4
#CPP = /lib/cpp -C -P
#CPPFLAGS = -DMPI
#CFLAGS = -DNOUNDERSCORE -DMPI
#ARCH_OBJS = milliclock.o
#IWORDSIZE = 4
#RWORDSIZE = 4
#LWORDSIZE = 4
# 7e. DEC ALPHA/MPI/OpenMP (Thanks to Dave Sherden)
#    - For multi-threaded MPI processes (useful on dm-clusters of SMP
#      nodes; such as fir.mmm.ucar.edu), uncomment the definition
#      of the macro: SPECIAL_OMP.
#    - If running with MPICH (public domain MPI) uncomment
#      first set of definitions for MFC, MCC, MLD and LDOPTIONS. If using
#      the Compaq/DEC MPI, uncomment the second set.
#
#RUNTIME_SYSTEM = "alpha"
#MPP_TARGET=$(RUNTIME_SYSTEM)
### If using OpenMP for SMP parallelism on each MPI process ###
###SPECIAL_OMP = -omp
### If using MPICH ###
#MFC = f77
#MCC = mpicc
#MLD = mpi$f77
#LDOPTIONS = $(OMP)
### If using DEC MPI (e.g. on fir.mmm.ucar.edu) ###
###MFC = f90
###MCC = cc
###MLD = f90
###LDOPTIONS = -lmpi $(SPECIAL_OMP)
###FCFLAGS = -O4 -Olimit 2000 -fpe0 -align dcommons -align records \
###  -convert big_endian $(SPECIAL_OMP)
###LOCAL_LIBRARIES =
###MAKE = make -i -r
#AWK = awk
#SED = sed
#CAT = cat
#CUT = cut
#EXPAND = expand
#M4 = m4
#CPP = cpp -C -P
#CPPFLAGS = -DMPI -DDEC_ALPHA
#CFLAGS = -DMPI -DDEC_ALPHA
#ARCH_OBJS = milliclock.o
#IWORDSIZE = 4
#RWORDSIZE = 4
#LWORDSIZE = 4
#
# 7f. Fujitsu VPP
#
# These options have been updated for the newer VPP5000 system. If you
# find that you have trouble compiling on your system, try removing the
# -KA32 option from FCFLAGS, LDOPTIONS, CFLAGS and from
# MPP/RSL/RSL/makefile.vpp. Note that to successfully compile the RSL
# library (MPP/RSL/RSL) you need the following two environment variables
# set (syntax may vary with shells other than csh):
# Older systems:
#    setenv MPIINCDIR /usr/lang/mpi/include
#    setenv MPIILIBS ‘-Wl,-P -L/usr/lang/mpi/lib -lmpi -lmp’
# Newer systems:
#    setenv MPIINCDIR /usr/lang/mpi2/include32
#    setenv MPIILIBS ‘-Wl,-P -L/usr/lang/mpi2/lib32 -lmpi -lmp’
# Newer system had difficulty in compiling MPP/FLIC/FLIC/dm. If you have
# trouble with this program, please download
# ‘chmod ugo+x dm’ and copy into MPP/FLIC/FLIC. Or contact michalak@ucar.edu.
# RUNTIME_SYSTEM = "vpp"
# MPP_TARGET=$(RUNTIME_SYSTEM)
# MFC = ftt
# MCC = cc
# MLD = ftt
# FCFLAGS = -Sw -Wv,-Of,-te,-ilfunc,-noalias,-m3,-P255 -Oe,-P -Kfast -Pdos -lmpi -lmp -KA32
# LDOPTIONS = -Wl,-P -L$(MPILIBS) -lmpi -J -lmp -KA32
# LOCAL_LIBRARIES =
# MAKE = make -i -r
# AWK = awk
# SED = sed
# CAT = cat
# CUT = cut
# EXPAND = $(CAT)
# M4 = m4
# CPP = /lib/cpp -C -P
# CPPFLAGS = -DMPI -Dvpp -I$(MPIINCDIR)
# CFLAGS = -DMPI -Dvpp -I$(MPIINCDIR) -KA32
# ARCH_OBJS = milliclock.o
# IWORDSIZE = 4
# RWORDSIZE = 4
# LWORDSIZE = 4
# FLIC_MACROS = LMvpp.m4
# 7g. Linux PCs. Need Portland Group pgf77 and MPICH.
# The following information has been added to this file with MM5v3.2:
# This expects mpif77 and mpicc to be installed on your system in
# $(LINUX_MPIHOME)/bin. These should be configured to use the Portland Group
# pgf77 (v3 or higher) and gcc, respectively. For information on how to
# download, install, and configure mpich on your system, see:
# http://www.mcs.anl.gov/mpi/mpich
# Information on Portland Group compiler:
# http://www.pgroup.com
# If using a different Fortran compiler, modify FCFLAGS and LDOPTIONS as
# needed. The compiler should be capable of doing little- to big-endian
# conversion and it should understand integer (Cray-style) pointers. It
# is recommended that the same fortran compiler be used to compile
# mpich. Edit the LINUX_MPIHOME macro, below, to point to the top level mpich
# directory. See also:
# http://www.mmm.ucar.edu/mm5/mpp/linuxhelp.html (by Steve Webb, NCAR/RAP)
# Note for pgf77 on RedHat Linux6: patches available from Portland Group at:
# RUNTIME_SYSTEM = "linux"
# MPP_TARGET=$(RUNTIME_SYSTEM)
# LINUX_MPIHOME = /usr/local/mpich
# MFC = $(LINUX_MPIHOME)/bin/mpif77
# MCC = $(LINUX_MPIHOME)/bin/mpicc
# MLD = $(LINUX_MPIHOME)/bin/mpif77
# FCFLAGS = -O2 -Mcray=pointer -tp p6 -pc 32 -Mnoframe -byteswapi
# LDOPTIONS = -O2 -Mcray=pointer -tp p6 -pc 32 -Mnoframe -byteswapi
#LOCAL_LIBRARIES = -L$(LINUX_MPIHOME)/build/LINUX/ch_p4/lib -lfmpich -lmpich
#MAKE = make -i -r
#AWK = awk
#SED = sed
#CAT = cat
#CUT = cut
#EXPAND = expand
#M4 = m4
#CPP = /lib/cpp -C -P
#CPPFLAGS = -D_MPI -Dlinux
#CFLAGS = -D_MPI -I/usr/local/mpi/include
#ARCH_OBJS = milliclock.o
#IWORDSIZE = 4
#RWORDSIZE = 4
#LWORDSIZE = 4
#-----------------------------------------------
# Don’t touch anything below this line
#-----------------------------------------------
.F.i:
 $(RM) $@
 $(CPP) $(CPPFLAGS) $*.F > $@
 mv $*.i $(DEVTOP)/pick/$*.f
 cp $*.F $(DEVTOP)/pick
.c.o:
 $(RM) $@ & & \
 $(CC) -c $(CFLAGS) $*.c
.F.o:
 $(RM) $@
 $(CC) -c $(CFLAGS) $*.F
.F.f:
 $(RM) $@
 $(CPP) $(CPPFLAGS) $*.F > $@
.f.o:
 $(RM) $@
 $(FC) -c $(FCFLAGS) $*.f

8.16 Configure.user for PC

# Sections
# This configure.user.linux file is used to compile on PC running linux only.
# For options to compile on Unix systems, please use configure.user
# 1. System Variables
# 2. User Variables
# 3. Fortran options
# 3i. PC_PGF77 (Linux)
# 4. General commands
# 5. Options for making "./include/parame.incl"
# 6. Physics Options (memory related)
#
# 1. System Variables
#---------------------------------------------------------------
SHELL = /bin/sh
.SUFFIXES: .F .i .o .f
#---------------------------------------------------------------
# 2. User Variables
#---------------------------------------------------------------
# RUNTIME_SYSTEM- Currently supported systems.
# PC_PGF77
RUNTIME_SYSTEM = "PC_PGF77"
# 3. Fortran options
LIBINCLUDE = $(DEVTOP)/include

# 3i. PC running Linux and using pgf77 compiler
# You may also need to unlimit stacksize by typing
# limit stacksize unlimited
# or
# setenv MPSTKZ 8M
# (or bigger.)
# If your compiler supports both SGI and OpenMP parallel directives,
# you need -Mnosgimp in your FCFLAGS. Otherwise remove it.

# 3i1. PC_PGF77 (LINUX/Portland Group Inc.)
# pgf77 version 1.6 and above

FC = pgf77
FCFLAGS = -I$(LIBINCLUDE) -O2 -Mcray=pointer -tp p6 -pc 32 -Mnoframe -byteswapio
#FCFLAGS = -I$(LIBINCLUDE) -O2 -Mcray=pointer -tp p6 -pc 32 -Mnoframe -byteswapio -mp
#-Mnosgimp
CPP = /lib/cpp
CFLAGS = -O
CPPFLAGS = -I$(LIBINCLUDE)
LDOPTIONS = -O2 -Mcray=pointer -tp p6 -pc 32 -Mnoframe -byteswapio
#LDOPTIONS = -O2 -Mcray=pointer -tp p6 -pc 32 -Mnoframe -byteswapio -mp
LOCAL_LIBRARIES =
MAKE = make -i

# 4. General commands
AR = ar ru
RM = rm -f
RM_CMD = $(RM) *.CKP *.ln *.BAK *.bak *.o *.i core errs ,* ~ *.a \
.emacs_* tags TAGS make.log MakeOut *.f !
GREP = grep -s
CC = cc

# 5. Options for making ./include/param.eincl

# FDDAGD (integer)                  - "1" -> FDDA gridded run
FDDAGD = 0
# FDDAOBS (integer)                 - "1" -> FDDA obs run
FDDAOBS = 0
# MAXNES (integer)                  - Max Number of Domains in simulation
MAXNES = 2
# MIX,MJX (integer)                 - Maximum Dimensions of any Domain
MIX = 49
MJX = 52
# MKX (integer)                     - Number of half sigma levels in model
MKX = 23

# 6. Physics Options
# The first MAXNES values in the list will be used for the corresponding
# model nests; the rest in the list can be used to compile other options.
# The exception is FRAD, of which only the first value is used in the
# model,  
# (i.e., only one radiation option is used for all nests). The rest allow
# other options to be compiled.
#---------------------------------------------------------------
# IMPHYS - for explicit moisture schemes (array.integer)
IMPHYS = "4,4,1,1,1,1,1,1,1,1"
#            - Dry,stable,warm rain,simple ice,mix phase,
#            - graupel(gsfc),graupel(reisner2),schultz
#            - 1,2 , 3  , 4  , 5
#            - graupel(reisner2),schultz
#            - 6 , 7 , 8
MPHYSTBL = 0
#            - do not use look-up tables for moist physics
#            - use look-up tables for moist physics
#            - (currently only simple ice and mix phase
#                          are available)
# # ICUPA - for cumulus schemes (array.integer)
ICUPA = "3,3,1,1,1,1,1,1,1,1"
# # IBLTYP - for planetary boundary layer (array.integer)
#            - 0=no PBL fluxes,1=bulk,2=Blackadar,
#            - 3=Burk-Thompson,4=Eta M-Y,5=MRF,
#            - 6=Gayno-Seaman
IBLTYP = "5,5,2,2,2,2,2,2,2,1"
# # FRAD - for atmospheric radiation (integer)
# #            - Radiation cooling of atmosphere
# #            - 0=none,1=simple,2=cloud,3=ccm2,rrtm=4
FRAD = "2,0,0,0,0"
# # ISOIL - for multi-layer soil temperature model (integer)
# #            - 0=no,1=yes (only works with IBLTYP=2,5)
ISOIL = 1
# # ISHALLO (array.integer) - Shallow Convection Option
# #            - 1=shallow convection,0=No shallow convection
ISHALLO = "0,0,0,0,0,0,0,0,0,0"
#---------------------------------------------------------------
# Don’t touch anything below this line
#---------------------------------------------------------------

.c.o:
  $(RM) $@ & & 
  $(CC) -c $(CFLAGS) $*.c
.F.o:
  $(RM) $@
  $(FC) -c $(FCFLAGS) $*.F
.f.o:
  $(RM) $@
  $(FC) -c $(FCFLAGS) $*.f

8.17 mm5.deck

This is a Bourne shell script. Slight variations may exist on different machines.

#!/bin/sh
#
# Version 3 of mm5 job deck
#
# The mm5 executable (mm5.exe) expects to find the following files
# in the Run/ directory:
#          MMINPUT_DOMAIN1 -  ] output files from Interpf
#          BDYOUT_DOMAIN1 -
#          LOWBDY_DOMAIN1 -

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# TERRAIN_DOMAIN[2,3..] if running nests --> output from Terrain
# If it is a restart run:
#     RESTART_DOMAIN1[,2,3..] --> output from MM5 run: renamed from
#                                   SAVE_DOMAIN1[,2,3..]
# If it is gridded FDDA run with surface analysis nudging:
#     SFCFDDA_DOMAIN1[2,3,...]
# If it is observational nudging run:
#     MM5OBS_DOMAIN1[,2,3..] --> user-created observation files
# Output from a MM5 run:
#   If IFTAPE = 1
#     MMOUT_DOMAIN1[,2,3...] --> one output for each domain
#   If IFSAVE = TRUE
#     SAVE_DOMAIN1[,2,3...]  
# # temp files should be accessible
umask 022
# Sections
# 1. Options for namelist ("mmlif")
# 2. Running...

#-----------------------------------------------------------------------------
# 1. Options for namelist ("mmlif")
#-----------------------------------------------------------------------------
# The first dimension (column) of the arrays denotes the domain
# identifier.
# Col 1 = Domain #1, Col 2 = Dom #2, etc.

# cat > ./Run/oparam << EOF
&OPARAM
;
;       ************* FORECAST TIME AND TIME STEP ***************
TIMAX  = 720.,      ; forecast length in minutes
TISTEP = 240.,      ; coarse domain DT in model, use 3*DX
;
;       ************** OUTPUT/RESTART OPTIONS ***************
IFREST = .FALSE.,    ; whether this is a restart
IXTIMR  = 720,      ; restart time in minutes
IFSAVE = .TRUE.,     ; save data for restart
SVLAST  = .TRUE.,    ; T: only save the last file for restart
; F: save multiple files
SAVFRQ  = 360.,     ; how frequently to save data (in minutes)
IFTAPE  = 1,       ; model output: 0,1
TAPFRQ  = 180.,     ; how frequently to output model results (in minutes)
BUFFRQ  = 0.,      ; how frequently to split model output files
; (in minutes), ignored if < TAPFRQ
INCTAP = 1,1,1,1,1,1,1,1,1,1,1,1,1, ; multipliers of TAPFRQ for outputting
IFSKIP = .FALSE.,    ; whether to skip input files - DO NOT use this for
; restart
CDATEST = '1993-03-13_00:00:00', ; the DATE for the starting file
IFPRT = 0,         ; sample print out: =1, a lot of print
PRTFRQ = 720.,     ; Print frequency for sample output (in minutes)
MASCHK = 45,       ; mass conservation check (KTAU or no. of time steps)
&END
EOF
cat > ./Run/lparam << EOF
&LPARAM


1. user-chosen options I

RADFRQ = 30,;atmospheric radiation calculation frequency (in minutes)
IMVDIF = 1,;moist vertical diffusion in clouds - 0, 1 (IBLTYP=2,5 only)
IVQADV = 1,;vertical moisture advection uses log interpolation - 0,
;linear - 1
IVTADV = 1,;vertical temperature advection uses theta interpolation
; - 0, linear - 1
ITHADV = 1,;advection of temperature uses potential temperature - 1,
;standard - 0
ITPDIF = 1,;diffusion using perturbation temperature - 0,1
ICOR3D = 1,;3D Coriolis force - 0, 1
IFUPR = 1,;upper radiative boundary condition - 0, 1

2. do not change IBOUDY

IBOU = 3, 2, 2, 2, 2, 2, 2, 2, 2, 2, ;boundary conditions
; (fixed, time-dependent, relaxation -0,2,3)

3. keep the following 8 variables as they are
unless doing sensitivity runs

IFDRY = 0,;fake-dry run (no latent heating) - 0, 1
;for IMPHYS = 2,3,4,5,6,7 (requires ICUPA = 1)
IFSNOW = 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ;SNOW COVER EFFECTS - 0, 1
;only if snow data are generated in DATAGRID
ISFFLX = 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, ;surface fluxes - 0, 1
ITGFLG = 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, ;surface temperature prediction
; - 1:yes, 3:no
ISFFPAR = 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, ;surface characteristics - 0, 1
ICLOUD = 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, ;cloud effects on radiation - 0, 1
; currently for IFRAD = 1,2
IEVAP = 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, ;evap of cloud/rainwater - <0, 0, >0
; (currently for IMPHYS=3,4,5 only)

EOF

&NPARAM

************** NEST AND MOVING NEST OPTIONS ***************

LEVID = 0,1,2,1,1,1,1,1,1,1, ; level of nest for each domain
NUMNC = 1,1,2,1,1,1,1,1,1,1, ; ID of mother domain for each nest
NESTIX = 35, 49, 31, 46, 46, 46, 46, 46, 46, 46, ; domain size i
NESTJX = 41, 52, 31, 61, 61, 61, 61, 61, 61, 61, ; domain size j
NESTI = 1, 10, 8, 1, 1, 1, 1, 1, 1, 1, ; start location i
NESTJ = 1, 17, 9, 1, 1, 1, 1, 1, 1, 1, ; start location j
XSTNES = 0., 0., 900., 0., 0., 0., 0., 0., 0., 0., ; domain initiation
XENNES =1440.,1440.,1440.,720.,720.,720.,720.,720.,720.,720.; domain termination

IOVERW = 1, 2, 0, 0, 0, 0, 0, 0, 0, 0, ; overwrite nest input
; 0=interpolate from coarse mesh (for nest domains);
; 1=read in domain initial conditions
; 2=read in nest terrain file
IACTIV = 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, ; in case of restart: is this domain active?

************ MOVING NEST OPTIONS ************
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ; I move #3
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ; I move #4
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ; I move #5
IMOVEJ =
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ; J move #1
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ; J move #2
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ; J move #3
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ; J move #4
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ; J move #5
IMOVET =
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ; time of move #1
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ; time of move #2
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ; time of move #3
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ; time of move #4
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ; time of move #5

IFEED = 3, ; no feedback; 9-pt weighted average; 1-pt feedback w/o smoothing
; / light smoothing / heavy smoothing - 0,1,2,3, and 4

&END
EOF

cat > ./Run/pparam << EOF
&PPARAM
;
************* MISCELLANEOUS OPTIONS *************
;
The values for the following 5 variables are only used if ISFPAR = 0
;(i.e. only land/water surface catagories)
;
ZZLND   = 0.1, ; roughness length over land in meters
ZZWTR   = 0.0001, ; roughness length over water in meters
ALBLND  = 0.15, ; albedo
THINLD  = 0.04, ; surface thermal inertia
XMAVA   = 0.3, ; moisture availability over land as a decimal fraction
            ; of one
;
CONF    = 1.0, ; non-convective precipitation saturation threshold
           ; (=1: 100%)  

&END
EOF

cat > ./Run/fparam << EOF
&FPARAM
;
************* 4DDA OPTIONS *************
;
THE FIRST DIMENSION (COLUMN) IS THE DOMAIN IDENTIFIER:
COLUMN 1 = DOMAIN #1, COLUMN 2 = DOMAIN #2, ETC.
;
START TIME FOR FDDA (ANALYSIS OR OBS) FOR EACH DOMAIN
(IN MINUTES RELATIVE TO MODEL INITIAL TIME)
FDASTA=0.,0.,0.,0.,0.,0.,0.,0.,0.,0.
;
ENDING TIME FOR FDDA (ANALYSIS OR OBS) FOR EACH DOMAIN
(IN MINUTES RELATIVE TO Model INITIAL TIME)
FDAEND=780.,0.,0.,0.,0.,0.,0.,0.,0.,0.,
;
************* ANALYSIS NUDGING *************
;
THE FIRST DIMENSION (COLUMN) OF THE ARRAYS DENOTES THE
DOMAIN IDENTIFIER:
COLUMN 1 = DOMAIN #1, COLUMN 2 = DOMAIN #2, ETC.
;
THE SECOND DIMENSION (ROW OR LINE) EITHER REFERS TO THE 3D VS
SFC ANALYSIS OR WHICH VARIABLE IS ACCESSED:
LINE 1 = 3D, LINE 2 = SFC OR
LINE 1 = U, LINE 2 = V, LINE 3 = T, LINE 4 = Q
;
IS THIS A GRID 4DDA RUN? 0 = NO; 1 = YES
I4D= 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0

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; SPECIFY THE TIME IN MINUTES BETWEEN THE INPUT (USUALLY
; FROM INTERP) USED FOR GRID FDDA
DIFTIM=720.,720.,0.,0.,0.,0.,0.,0.,0.,0.,    ; 3D ANALYSIS NUDGING
180.,180.,0.,0.,0.,0.,0.,0.,0.,0.,    ; SFC ANALYSIS NUDGING
;
; GRID NUDGE THE WIND FIELD? 0 = NO; 1 = YES
IWIND=1,1,0,0,0,0,0,0,0,0,    ; 3D ANALYSIS NUDGING
1,1,0,0,0,0,0,0,0,0,    ; SFC ANALYSIS NUDGING
;
; NUDGING COEFFICIENT FOR WINDS ANALYSES
GV=2.5E-4,1.0E-4,0.,0.,0.,0.,0.,0.,0.,0.,    ; 3D ANALYSIS NUDGING
2.5E-4,1.0E-4,0.,0.,0.,0.,0.,0.,0.,0.,    ; SFC ANALYSIS NUDGING
;
; GRID NUDGE THE TEMPERATURE FIELD? 0 = NO; 1 = YES
ITEMP=1,1,0,0,0,0,0,0,0,0,    ; 3D ANALYSIS NUDGING
1,1,0,0,0,0,0,0,0,0,    ; SFC ANALYSIS NUDGING
;
; NUDGING COEFFICIENT FOR TEMPERATURE ANALYSES
GT=2.5E-4,1.0E-4,0.,0.,0.,0.,0.,0.,0.,0.,    ; 3D ANALYSIS NUDGING
2.5E-4,1.0E-4,0.,0.,0.,0.,0.,0.,0.,0.,    ; SFC ANALYSIS NUDGING
;
; GRID NUDGE THE MIXING RATIO FIELD? 0 = NO; 1 = YES
IMOIS=1,1,0,0,0,0,0,0,0,0,    ; 3D ANALYSIS NUDGING
1,1,0,0,0,0,0,0,0,0,    ; SFC ANALYSIS NUDGING
;
; NUDGING COEFFICIENT FOR THE MIXING RATIO ANALYSES
GQ=1.E-5,1.E-5,0.,0.,0.,0.,0.,0.,0.,0.,    ; 3D ANALYSIS NUDGING
1.E-5,1.E-5,0.,0.,0.,0.,0.,0.,0.,0.,    ; SFC ANALYSIS NUDGING
;
; GRID NUDGE THE ROTATIONAL WIND FIELD? 0 = NO; 1 = YES
IROT=0,0,0,0,0,0,0,0,0,0,     ; 3D ANALYSIS NUDGING
;
; NUDGING COEFFICIENT FOR THE ROTATIONAL COMPONENT OF THE WINDS
GR=5.E6,5.E6,0.,0.,0.,0.,0.,0.,0.,0.,    ; 3D ANALYSIS NUDGING
;
; IF GRID NUDGING (I4D(1,1)=1) AND YOU WISH TO EXCLUDE THE
; BOUNDARY LAYER FROM FDDA OF COARSE GRID THREE DIMENSIONAL
; DATA (USUALLY FROM INTERP),
; 0 = NO, INCLUDE BOUNDARY LAYER NUDGING
; 1 = YES, EXCLUDE BOUNDARY LAYER NUDGING
INONBL =0,0,0,0,0,0,0,0,0,0,    ; U WIND
0,0,0,0,0,0,0,0,0,0,    ; V WIND
1,1,1,1,1,1,1,1,1,1,    ; TEMPERATURE
1,1,1,1,1,1,1,1,1,1,    ; MIXING RATIO
;
; RADIUS OF INFLUENCE FOR SURFACE ANALYSIS (KM).
; IF I4D(2,1)=1 OR I4D(2,2)=1, ETC, DEFINE RINBLW (KM) USED
; IN SUBROUTINE BLW TO DETERMINE THE HORIZONTAL VARIABILITY
; OF THE SURFACE-ANALYSIS NUDGING AS A FUNCTION OF SURFACE
; DATA DENSITY. OVER LAND, THE STRENGTH OF THE SURFACE-
; ANALYSIS NUDGING IS LINEARLY DECREASED BY 80 PERCENT AT
; THOSE GRID POINTS GREATER THAN RINBLW FROM AN OBSERVATION
; TO ACCOUNT FOR DECREASED CONFIDENCE IN THE ANALYSIS
; IN REGIONS NOT NEAR ANY OBSERVATIONS.
RINBLW=250.,
;
; SET THE NUDGING PRINT FREQUENCY FOR SELECTED DIAGNOSTIC
; PRINTS IN THE GRID (ANALYSIS) NUDGING CODE (IN CGM
; TIMESTEPS)
NPFG=50,

*************** OBSERVATION NUDGING ***************

INDIVIDUAL OBSERVATION NUDGING. VARIABLES THAT ARE ARRAYS
USE THE FIRST DIMENSION (COLUMN) AS THE DOMAIN IDENTIFIER:
COLUMN 1 = DOMAIN #1, COLUMN 2 = DOMAIN #2, ETC.
 IS THIS INDIVIDUAL OBSERVATION NUDGING? 0 = NO; 1 = YES
I4DI  =0,0,0,0,0,0,0,0,0,0,
    
 OBS NUDGE THE WIND FIELD FROM STATION DATA? 0 = NO; 1 = YES
ISWIND =1,0,0,0,0,0,0,0,0,0,
    
 NUDGING COEFFICIENT FOR WINDS FROM STATION DATA
GIV  =4.E-4,4.E-4,0.,0.,0.,0.,0.,0.,0.,
    
 OBS NUDGE THE TEMPERATURE FIELD FROM STATION DATA? 0 = NO; 1 = YES
ISTEMP=1,0,0,0,0,0,0,0,0,0,
    
 NUDGING COEFFICIENT FOR TEMPERATURES FROM STATION DATA
GIT  =4.E-4,4.E-4,0.,0.,0.,0.,0.,0.,
    
 OBS NUDGE THE MIXING RATIO FIELD FROM STATION DATA? 0 = NO; 1 = YES
ISMOIS=1,0,0,0,0,0,0,0,0,0,
    
 NUDGING COEFFICIENT FOR THE MIXING RATIO FROM STATION DATA
GIQ  =4.E-4,4.E-4,0.,0.,0.,0.,0.,0.,
    
 THE OBS NUDGING RADIUS OF INFLUENCE IN THE
 HORIZONTAL IN KM FOR CRESSMAN-TYPE DISTANCE-WEIGHTED
 FUNCTIONS WHICH SPREAD THE OBS-NUDGING CORRECTION
 IN THE HORIZONTAL.
RINXY=240.,
    
 THE OBS NUDGING RADIUS OF INFLUENCE IN THE
 VERTICAL IN SIGMA UNITS FOR CRESSMAN-TYPE DISTANCE-
 WEIGHTED FUNCTIONS WHICH SPREAD THE OBS-NUDGING
 CORRECTION IN THE VERTICAL.
RINSIG=0.001,
    
 THE HALF-PERIOD OF THE TIME WINDOW, IN MINUTES, OVER
 WHICH AN OBSERVATION WILL AFFECT THE FORECAST VIA OBS
 NUDGING. THAT IS, THE OBS WILL INFLUENCE THE FORECAST
 FROM TIMEOBS-TWINDO TO TIMEOBS+TWINDO. THE TEMPORAL
 WEIGHTING FUNCTION IS DEFINED SUCH THAT THE OBSERVATION
 IS APPLIED WITH FULL STRENGTH WITHIN TWINDO/2. MINUTES
 BEFORE OR AFTER THE OBSERVATION TIME, AND THEN LINEARLY
 DECREASES TO ZERO TWINDO MINUTES BEFORE OR AFTER THE
 OBSERVATION TIME.
TWINDO=40.0,
    
 THE NUDGING PRINT FREQUENCY FOR SELECTED DIAGNOSTIC PRINT
 IN THE OBS NUDGING CODE (IN CGM TIMESTEPS)
NPFI=20,
    
 FREQUENCY (IN CGM TIMESTEPS) TO COMPUTE OBS NUDGING WEIGHTS
IONF=2,
IDYNIN=0, ;for dynamic initialization using a ramp-down function to gradually
 turn off the FDDA before the pure forecast, set idynin=1 [y=1, n=0]
DTRAMP=60.,;the time period in minutes over which the
 nudging (obs nudging and analysis nudging) is ramped down
 from one to zero. Set dtramp negative if FDDA is to be ramped
 down BEFORE the end-of-data time (DATEND), and positive if the
 FDDA ramp-down period extends beyond the end-of-data time.
&END
EOF

# create namelist: mmlif, and remove comments from namelist:
#
make mmlif
make mmlif

cd ./Run
sed -f ../Util/no_comment.sed mmlif | grep [A-Z,a-z] > mmlif.tmp
mv mmlif.tmp mmlif
rm fparam lparam nparam oparam pparam
#
#-------------------------------------
#
#       run MM5
#
# date
echo "timex mm5.exe >! mm5.print.out "
timex mm5.exe > mm5.print.out 2>&1
# List of MM5 Fortran files

## MM5 FORTRAN FILES

### Run
- mm5.F
  - include
    - add0.incl
    - adstr.incl
    - adstr3.incl
    - adstr4.incl
    - adstrs.incl
    - address
      - addlst.F
      - addx1c.F
      - addx1.F
  - fdda
    - grid:
      - bbrgd.F
      - blmavg.F
      - bbw.F
      - bwsld.F
      - bwsld.F
      - conv.F
      - in44grd.F
      - int44grd.F
      - nofro.F
      - nudg.F
      - p44gat.F
      - setupd.F
    - obs:
      - eroth.F
      - in4s.F
      - nudof.F
      - util:
        - fdlst.F
        - unity.F
        - set.F
  - boundary:
    - bdyin.F
    - bdybn.F
    - bdybn.F
    - nudye.F
  - drivers:
    - nstlev.F
    - nstlev2.F
    - nstlev3.F
    - initial:
      - init.F
      - par4m.F
      - p4m.F
    - io:
      - conav4.F
      - in4.F
      - in4.F
      - out4.F
      - output.F
      - output.F
      - rdm1.F
      - sav4.F
      - save4.F
      - trn4.F
      - trn4.F
      - write_big.
  - nest:
    - bdyv11.F
    - chkn4.F
    - exaint.F
    - exeh4n.F
    - exeh4n.F
    - feedback.F
    - filsh.F
    - intn4.F
    - intn4.F
    - out4.F
    - out4.F
    - rdm1.F
    - sav4.F
    - save4.F
    - trn4.F
    - trn4.F
    - write_big.
  - util:
    - couple.
    - date.F
    - dots.F
    - dcpp13.1.F
    - dcpp13.1.F
    - equ4nte.F
    - equ4nte.F
    - fill.F
    - scaps.F
    - skip.F
    - sm2.F
    - smth.F
    - xidot.F

### Domain
- domain:
  - physics
    - advection/simple:
      - hadv.F
      - ncnadv.F
    - explicit/nonconv:
      - ncnadv.F
    - explicit/simple:
      - exmoiss.F
      - lexmoiss.F
    - explicit/rei.
      - exmoisr.F
      - lexmoisr.F
    - cumulus/:
      - aram4.F
      - ar4ote.F
      - ar4oas.F
      - cl4oudw.
      - cloudw.
      - capara4.
      - ent.F
      - kero.F
      - sound.d.
      - sound.d.
      - s4pline.F
      - t4pc.F
      - cumulus/sc:
        - capara5.
        - fcpara.F
        - tp.F
      - cumulus/grav.
        - cup.
        - capara3.
        - maxim.F
      - minim.
      - cumulus/so:
        - cond4int.
        - capara6.
        - diffrz.F
        - diffrznw.
        - env4rnit.
        - k4fara.F
        - prof.F
        - prof.F
        - tp4dd.
        - tmix.F
      - cumulus/wh:
        - ar4oas.
        - cl4oudw.
        - entr.
        - kero.F
        - sh4llc.
        - sh4llc.
      - cumulus/sh:
        - b4l.
        - mb4l.
        - mph4l.
        - n4mph.
        - ou4p.F
        - u4vcmp.F
      - cumulus/shar:
        - kbd4nt.
        - heipre.
        - diffrz.F
        - maxim.F
        - minim.F
        - moen.
        - precip.F
        - zinc.F
    - dynamics
      - nonhydro:
        - d4coef.F
        - de4v.F
        - krt.F
        - hrtic.F
        - hst4e.F
        - hst4e.F
        - nx4c.F
        - x4td5n.F
        - x4td5n.F
        - f Cous.
        - s4n.
        - c4nn.
        - c4nd.
        - r4d.
        - rad.
        - rad.
        - cal.
        - cal.
        - sc4n.
        - sc4n.
        - c4nn.
        - c4nn.
        - c4nd.
        - c4nd.
        - r4d.
        - r4d.
        - cal.
        - cal.
        - sc4n.
        - sc4n.
        - c4nn.
        - c4nn.
        - c4nd.
        - c4nd.
        - r4d.
        - r4d.
        - cal.
        - cal.
        - sc4n.
        - sc4n.
        - c4nn.
        - c4nn.
        - c4nd.
        - c4nd.
        - r4d.
        - r4d.
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        - sc4n.
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        - sc4n.
        - sc4n.
        - c4nn.
        - c4nn.
        - c4nd.
        - c4nd.
        - r4d.
        - r4d.