Set Up and Run WRF

(*real* and *Ideal* data)

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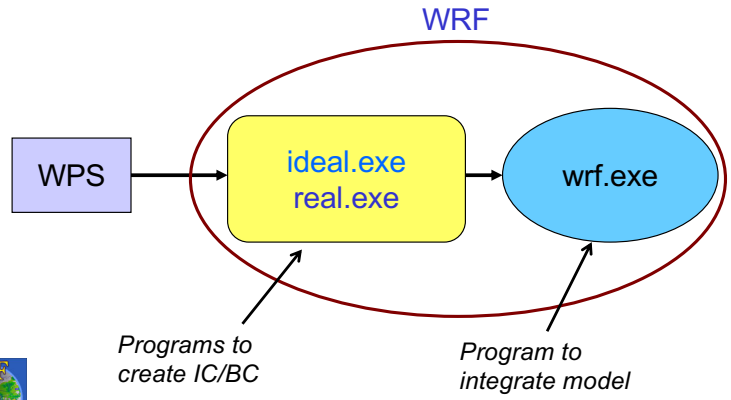
WRF System Flowchart



Outline

- Running WRF code
  - Things to check before you run..
  - Running real-data case
  - Running idealized case
- Basic runtime options for a ***single*** domain run (*namelist*)
- Check output
- Simple trouble shooting
- Running a nested case: later

Before You Run ..

- Top directory is now **`WRF/`**
- Make sure appropriate executables are created in **`WRF/main/`** directory:
  - **`ideal.exe`** – *executable to create idealized IC*
  - **`real.exe`** – *executable to create IC/BC*
  - **`wrf.exe`** – *executable for model integration*
  - **`ndown.exe`** – *utility*
  - **`tc.exe`** – *utility routine for TC bogusing*
- If you are working with real data, be sure that files for ***a few time periods*** from WPS are correctly generated:
  - **`met_em.d01.*`**

WRF test case directories

You have these choices in **`WRF/test/`**

(choices made at compile time. E.g. ***`compile em_real`***):

- `em_real` } *3-dimensional real-data – real.exe*
- `em_quarter_ss`
- `em_b_wave`
- `em_les`
- `em_tropical_cyclone`
- `em_heldsuarez` } *3d ideal*
- `em_hill2d_x`
- `em_squall2d_x`
- `em_squall2d_y`
- `em_grav2d_x`
- `em_seabreeze2d_x` } *2d ideal*
- `em_scm_xy` } *1d ideal*

ideal.exe

Steps to Run

1. cd to *run/* or one of the *test case* directories
2. Move or link WPS output files to the directory for real-data cases
3. Edit *namelist.input* file for the appropriate grid dimensions and times of the case
4. Run a initialization program (***`ideal.exe`*** or ***`real.exe`***)
5. Run model executable, ***`wrf.exe`***

WRF/run directory

- `README.namelist` } *description of namelists*
- `LANDUSE.TBL`
- `GENPARM.TBL`
- `SOILPARM.TBL`
- `VEGPARM.TBL`
- `URBPARM.TBL`
- `RRTM_DATA`
- `RRTMG_SW_DATA`
- `RRTMG_LW_DATA`
- `CAM_ABS_DATA`
- `CAM_AEROPT_DATA`
- `ozone.formatted`
- `ozone_lat.formatted`
- `ozone_plev.formatted`
- `aerosol.formatted`
- `aerosol_lat.formatted`
- `aerosol_lon.formatted`
- `aerosol_plev.formatted`

These are model physics data files: they are used to either initialize physics variables, or make physics computation faster

** Some of these files are text files, hence editable*

- `gribmap.txt`
- `grib2map.tbl` } *for grib IO*
- …. (a total of 60 files)

WRF/run directory after compile

`LANDUSE.TBL`
`SOILPARM.TBL`
`VEGPARM.TBL`
`GENPARM.TBL`
`URBPARM.TBL`
`RRTM_DATA`
`RRTMG_SW_DATA`
`RRTMG_LW_DATA`
`ozone.formatted`
`ozone_lat.formatted`
`ozone_plev.formatted`
…

An example after em_real case compile

`namelist.input` *- copied from* **`../test/em_real/namelist.input`**
`real.exe -> ../main/real.exe`
`wrf.exe -> ../main/wrf.exe`
`ndown.exe -> ../main/ndown.exe`
…. (a few more)

Running a Real-Data Case

Running a Real-Data Case

- If you have compiled the *em_real* case, you should have:

  real.exe - *real data initialization program*

  wrf.exe - *model executable*

  ndown.exe - *program for doing one-way nesting*

  tc.exe - *program for TC bogusing*

- These executables are linked to:

  WRF/run

  and

  WRF/test/*em_real*

➔ One can go to either directory to run.

WRF/test/em_*real* directory

```
LANDUSE.TBL -> ../../run/LANDUSE.TBL
GENPARM.TBL -> ../../run/GENPARM.TBL
SOILPARM.TBL -> ../../run/SOILPARM.TBL
VEGPARM.TBL -> ../../run/VEGPARM.TBL
URBPARM.TBL -> ../../run/URBPARM.TBL
RRTM_DATA -> ../../run/RRTM_DATA
RRTMG_SW_DATA -> ../../run/RRTMG_SW_DATA
RRTMG_LW_DATA -> ../../run/RRTMG_LW_DATA
ozone.formatted -> ../../run/ozone.formatted
ozone_lat.formatted -> ../../run/ozone_lat.formatted
ozone_plev.formatted -> ../../run/ozone_plev.formatted
…
namelist.input                  - editing required
real.exe -> ../../main/real.exe
wrf.exe -> ../../main/wrf.exe
ndown.exe -> ../../main/ndown.exe
…. (many more)
```

Running a Real-data Case

- One must successfully run WPS to prepare data required, and create **met_em.*** files for *multiple time periods* for initial and boundary conditions

- Move or link WPS/metgrid output files to the run directory:

```
cd test/em_real
ln -s ../../../WPS/met_em.d01.* .
```

Running a Real-data Case

- Edit **namelist.input** file for runtime options (*at mininum*, one must edit **&time_control** for start, end and integration times, and **&domains** for grid dimensions)
- Run the real-data initialization program:
  ./real.exe if compiled serially / SMP, or

  mpirun -np *N* ./real.exe for a MPI job

  where ***N*** is the number of processors requested.

Running a Real-data Case

- Successfully running **real.exe** will create model initial and boundary files:

wrfinput_d01 ← *Single time level data at model's start time*

wrfbdy_d01 ← *N-1 time-level data for lateral boundaries, and only for domain 1*

N: the number of time periods processed

ncdump -v Times wrfbdy_d01

Running a Real-data Case

- Typing '**ncdump -v Times wrfbdy_d01**' will give you, for a 24 hour period, 6 hourly data interval:

.. a bunch of prints and at the end:

```
data:
 Times =
  "2005-08-28_00:00:00",
  "2005-08-28_06:00:00",
  "2005-08-28_12:00:00",
  "2005-08-28_18:00:00" ;
```

* BC data consists of values at the start of the time interval and rate of change in the time interval.

Running a Real-data Case

- Run the model executable by typing:
  ./wrf.exe >& wrf.out &
  or
  mpirun -np *N* ./wrf.exe &
- Successfully running the model will a create model *history* file:
  wrfout_d01_2005-08-28_00:00:00

  Based on start date set in namelist

  and a *restart* file if **restart_interval** is set to a time within the range of the forecast time:
  wrfrst_d01_2005-08-28_12:00:00

  Exact time at a restart

Running a Real Data Case

wrfout_d01_2005-08-28_00:00:00

Based on start date set in namelist

```
start_year                          = 2008, 2008, 2008,
start_month                         = 08,   08,   08,
start_day                           = 28,   28,   28,
start_hour                          = 00,   00,   00,
start_minute                        = 00,   00,   00,
start_second                        = 00,   00,   00,
end_year                            = 2008, 2008, 2008,
end_month                           = 08,   08,   08,
end_day                             = 29,   29,   29,
end_hour                            = 00,   00,   00,
end_minute                          = 00,   00,   00,
end_second                          = 00,   00,   00,
```

Running an Idealized Case

Running an *Idealized* Case

- An idealized case refers to data in the initial condition file (no need to run WPS)
- If you have compiled an ideal case, you should have:

  ideal.exe – program to create idealized initial condition

  wrf.exe - model executable
- These executables are linked to:

  WRF/run

  and

  WRF/test/*em_test-case*

➔ One can go to either directory to run.

Running an *Idealized* Case

Go to the desired *ideal* test case directory: e.g.

cd test/em_quarter_ss

If there is '**run_me_first.csh**' in the directory, run it first - this links relevant physics data files to the current directory:

./run_me_first.csh

Running an *Idealized* Case

Then run the ideal initialization program:

`./ideal.exe`

The input to this program is typically a sounding file (file named ***input_sounding***), or a pre-defined 2D input (e.g. ***input_jet*** in **em_b_wave** case).

Running **ideal.exe** *only* creates WRF initial condition file: **wrfinput_d01**

Running an *Idealized* Case

Note that wrfbdy file is not needed for idealized cases.

Instead, the boundary condition options are set in the **namelist.input** file. For example, these are for options in east-west, or x direction:

```
periodic_x      = .true.,
symmetric_xs    = .false.,
symmetric_xe    = .false.,
open_xs         = .false.,
open_xe         = .false.,
```

Running an *Idealized* Case

- To run the model interactively, type

  `./wrf.exe >& wrf.out &`

  for single processor (serial) or SMP run. Or

  `mpirun -np N ./wrf.exe &`

  for a MPI run (3D cases only)
- Successful running of the model executable will create a model history file called **wrfout_d01_<date>**

  e.g. wrfout_d01_0001-01-01_00:00:00

  Based on start date set in namelist

  (dates are important for radiation physics)

Running an *Idealized* Case

wrfout_d01_0001-01-01_00:00:00

Based on start date set in namelist

```
start_year                          = 0001, 0001, 0001,
start_month                         = 01,   01,   01,
start_day                           = 01,   01,   01,
start_hour                          = 00,   00,   00,
start_minute                        = 00,   00,   00,
start_second                        = 00,   00,   00,
end_year                            = 0001, 0001, 0001,
end_month                           = 01,   01,   01,
end_day                             = 01,   01,   01,
end_hour                            = 00,   00,   00,
end_minute                          = 120,  120,  120,
end_second                          = 00,   00,   00,
```

Running an *Idealized* Case

- Edit **`namelist.input`** file to change options.
- For your own case, you may provide a different sounding.
- You may also edit **`dyn_em/module_initialize_<case>.F`** to change other aspects of the initialization (*more on Thur.*)

***Note*:**

- For 2D cases and baroclinic wave case, **`ideal.exe`** must be run serially
- For all 2D cases, **`wrf.exe`** must be run serially or with SMP
- For the 1D case, compile and run serially

Basic namelist Options

What is a namelist?

- A Fortran namelist contains a list of *runtime* options for the code to read in during its execution. Use of a namelist allows one to change runtime configuration without the need to recompile the source code.
- Fortran 90 namelist has very specific format, so edit with care:

  `&namelist-record` - start

  `/` - end
- As a general rule:
  - Multiple columns: domain dependent
  - Single column: value valid for all domains
- A namelist file may contain a number of records

namelist record **`&time_control`**

```
run_days                = 0,
run_hours               = 24,
run_minutes             = 0,
run_seconds             = 0,
start_year              = 2000, 2000, 2000,
start_month             = 01,   01,   01,
start_day               = 24,   24,   24,
start_hour              = 12,   12,   12,
start_minute            = 00,   00,   00,
start_second            = 00,   00,   00,
end_year                = 2000, 2000, 2000,
end_month               = 01,   01,   01,
end_day                 = 25,   25,   25,
end_hour                = 12,   12,   12,
end_minute              = 00,   00,   00,
end_second              = 00,   00,   00,
interval_seconds        = 21600
history_interval        = 180,  60,   60,
frames_per_outfile      = 1000, 1000, 1000,
restart_interval        = 360,
restart                 = .true.,
```

domain 1 option

for nests

Notes on &time_control

- *run_** time variables:
  - Model simulation length: *wrf.exe* and domain 1 only
- *start_** and *end_** time variables:
  - Program *real* will use WPS output between these times to produce lateral (and lower) boundary file
  - They can also be used to specify the start and end of simulation times for the coarse grid if *run_** variables are not set (or set to 0)

Notes on &time_control

- *interval_seconds*:
  - Time interval between WPS output times, and lateral BC (and lower BC) update frequency
- *history_interval*:
  - Time interval in minutes when a history output is written (*note* output is instantaneous)
  - If the **time_step** cannot be evenly divided by **history_interval**, then nearest time step output is used
  - The time stamp in a history file name is the time when the history file is first written, and multiple time periods may be written in one file. e.g. a history file for domain 1 that is first written for 1200 UTC Jan 24 2000 is

    wrfout_d01_2000-01-24_12:00:00

Notes on &time_control

- *frames_per_outfile*:
  - Number of history times written to one file
- *restart_interval*:
  - Time interval in minutes when a restart file is written
  - By default, restart file is not written at hour 0
  - A restart file contains only one time level data, and its valid time is in its file name, e.g. a restart file for domain 1 valid for 0000 UTC Jan 25 2000 is

    wrfrst_d01_2000-01-25_00:00:00
- *restart:*
  - whether this is a restart run

Notes on &time_control

Example 1: all output times are in a single file

```
history_interval    = 180,   60,    60,
frames_per_outfile = 1000, 1000, 1000,
```

wrfout_d01_2000-01-24_12:00:00

Example 2: each output file only contains a single time

```
history_interval   = 180, 60,   60,
frames_per_outfile = 1,    1,    1,
```

wrfout_d01_2000-01-24_12:00:00
wrfout_d01_2000-01-24_15:00:00
wrfout_d01_2000-01-24_18:00:00

Notes on *restart*

- What is a *restart* run?
  - A restart run is a continuation of a model run
- How to do a *restart* run:
  - In the first run, set *restart_interval* to a value that is within the model integration time
  - A restart file will be created. e.g.

    wrfrst_d01_2000-01-25_00:00:00
- When doing a restart run:
  - Set *restart* = .true.,
  - Set start time to restart time
  - Set run_* to be the hours remaining in the run

&time_control

```
io_form_history      = 2,
io_form_restart      = 2,
io_form_input        = 2,
io_form_boundary     = 2,
```

IO format options:
- = 1, binary
- = 2, netcdf (most common)
- = 4, PHDF5
- = 5, Grib 1
- =10, Grib 2
- =11, pnetCDF

For large files:
io_form_restart = 102 : write output in patch sizes: fast for large grid and useful for restart file

namelist record &domains

```
time_step                = 180
time_step_fract_num      = 0,
time_step_fract_den      = 1,
max_dom                  = 1,
e_we                     = 74,    112,    94,
e_sn                     = 61,    97,     91,
e_vert                   = 33,    28,     28,
num_metgrid_levels       = 32,
num_metgrid_soil_levels  = 4
dx                       = 30000, 10000,  3333,
dy                       = 30000, 10000,  3333,
eta_levels               = 1.0,0.996,0.99,0.98,… 0.0
p_top_requested          = 5000,
```

nest options

Notes on &domains

- *time_step, time_step_fract_num, time_step_frac_den*:
  - Time step for model integration in seconds
  - Fractional time step specified in separate integers of numerator and denominator
  - Typically 5 to 6xDX (DX is grid distance in km)
- *e_we, e_sn, e_vert*:
  - Model grid dimensions (staggered) in X, Y and Z directions, need to match those defined in *geogrid* program
- *num_metgrid_levels*:
  - Number of *metgrid* (input) data levels
- *num_metgrid_soil_levels*:
  - Number of soil data levels in the input data

⇨ Both can be found by typing **ncdump -h met_em.d01.<date> | more**

- *dx, dy*:
  - grid distance: in meters

Notes on &domains

- *p_top_requested*:
  - Pressure value at the model top
  - Constrained by the available data from WPS
  - Default is 5000 Pa (recommended as lowest model top)
- *eta_levels*:
  - Specify your own model levels from 1.0 to 0.0
  - If not specified, program *real* will calculate a set of levels
    - V4 has a new and better way to compute the levels
  - Use a minimum of 33 ore more levels with 5000 Pa model top to limit vertical grid distance < 1 km. Use more vertical levels when decreasing horizontal grid sizes.

namelist record &bdy_control

typical *optional*

```
spec_bdy_width      = 5, (10)
spec_zone           = 1, (1)      <-- do not change
relax_zone          = 4, (9)
specified           = .true.,
nested              = .false.,
```

May change ***relax_zone*** and ***spec_bdy_width***
(spec_zone + relax_zone = spec_bdy_width)

* Wider boundary zone may work better for coarser driving data

Other namelists

&physics:
- Model physics options

&dynamics:
- Damping, diffusion options
- Advection options
- In 4.0, the hybrid vertical coordinate option is the default. Turn it off by setting the following for *real* and *wrf*:

```
hybrid_opt          = 0
```

Where do I start?

- Always start with a *namelist* template provided in a test case directory, whether it is an ideal case, or a real data case.
  - A number of namelist templates are provided in *test/test_<case>/* directories

For example: in *test/em_real/*, there are

namelist.input.4km ~ 4 km grid size

namelist.input.jun01 ~ 10 km grid size

namelist.input.jan00 ~ 30 km grid size

Where do I start?

- For different applications, please refer to p5-38 to 5-40 of the ARW User's Guide:
  - 2 or 4 km microphysics-only runs
  - 20 – 30 km, 2 – 3 day runs
  - Antarctic region
  - Tropical storm forecasting
  - Regional climate
  - Try physics suites (since V3.9)

Where do I start?

- Use document to guide the modification of the namelist values:
  - **`run/README.namelist`**
  - **`test/em_real/examples.namelist`**
  - User's Guide, Chapter 5 (online version has the latest)
  - Full list of namelists and their default values can be found in Registry files: Registry.EM_COMMON, registry.io_boilerplate (for IO options) and other registry files - look for character string '*namelist*'

To run a job in a different directory..

- Directories *run/* and test_<*case*>/ are convenient places to run, but it does not have to be.
- Copy or link the content of these directories to another directory, including physics data files, wrf input and boundary files, wrf namelist and executables, and you should be able to run a job anywhere on your system.

Check Output

Output After a Model Run

- Standard out/error files:
  `wrf.out`, or **`rsl`**.* files
- Model history file(s):
  `wrfout_d01_<date>`
- Model restart file(s), optional
  `wrfrst_d01_<date>`

Output from a multi-processor run

The standard out and error will go to the following files for a MPI run:

```
mpirun -np 4 ./wrf.exe ➔
```

```
rsl.out.0000        rsl.error.0000
rsl.out.0001        rsl.error.0001
rsl.out.0002        rsl.error.0002
rsl.out.0003        rsl.error.0003
```

There is one pair of files for each processor requested

What to Look for in a standard out File?

Check run log file by typing

```
tail wrf.out, or
tail rsl.out.0000
```

You should see the following if the job is successfully completed:

```
wrf: SUCCESS COMPLETE WRF
```

How to Check Model History File?

- Use **`ncdump`**:

```
ncdump -v Times wrfout_d01_<date>
```

to check output times. Or

```
ncdump -v U wrfout_d01_<date>
```

to check a particular variable (U)

- Use **`ncview`** (great tool!)
- Use post-processing tools (see talks later)

What is in a *wrf.out* or *rsl* file?

- Model version, decomposition info:

```
Ntasks in X            2, ntasks in Y           4
WRF V4.0 MODEL
```

- Time taken to compute one model step:

```
Timing for main: time 2000-01-24_20:03:00 on domain   1:    0.89475 elapsed seconds
Timing for main: time 2000-01-24_20:06:00 on domain   1:    0.09011 elapsed seconds
Timing for main: time 2000-01-24_20:09:00 on domain   1:    0.08634 elapsed seconds
Timing for main: time 2000-01-24_20:12:00 on domain   1:    0.09004 elapsed seconds
```

- Time taken to write history and restart file:

```
Timing for Writing wrfout_d01_2000-01-25_00:00:00 for domain   1:   0.07091 elapsed seconds
```

- Any model error prints:

```
5 points exceeded cfl=2 in domain 1 at time 4.200000 MAX AT i,j,k: 123 48 3
    cfl,w,d(eta)= 4.165821
```

→ An indication the model has become numerically unstable

Simple Trouble Shooting

Often-seen runtime problems

– `module_configure: initial_config: error reading namelist: &dynamics`

> Typos or erroneous namelist variables exist in namelist record *&dynamics* in *namelist.input* file

– `input_wrf.F: SIZE MISMATCH: namelist ide,jde,num_metgrid_levels= 70 61 27 ; input data ide,jde,num_metgrid_levels= 74 61 27`

> Grid dimensions in error

Often-seen runtime problems

– `Segmentation fault (core dumped)`

> Often typing '**`unlimit`**' or '**`ulimit -s unlimited`**' or equivalent can help when this happens quickly in a run, and on a small computer

– If you do: `grep cfl rsl.error.*` and see

```
121 points exceeded cfl=2 in domain 1 at time
4.200000 MAX AT i,j,k: 123 48 3 cfl,w,d(eta)=
4.165821
```

> Model becomes unstable due to various reasons. If it happens soon after the start time, check input data, and/or reduce time step.

References

- Information on compiling and running WRF, and a more extensive list of namelist options and their definition / explanations can be found in the User's Guide, Chapter 5
- Also see nesting talk and demonstration tomorrow.