Set Up and Run WRF
(ARW-Ideal and ARW-real)

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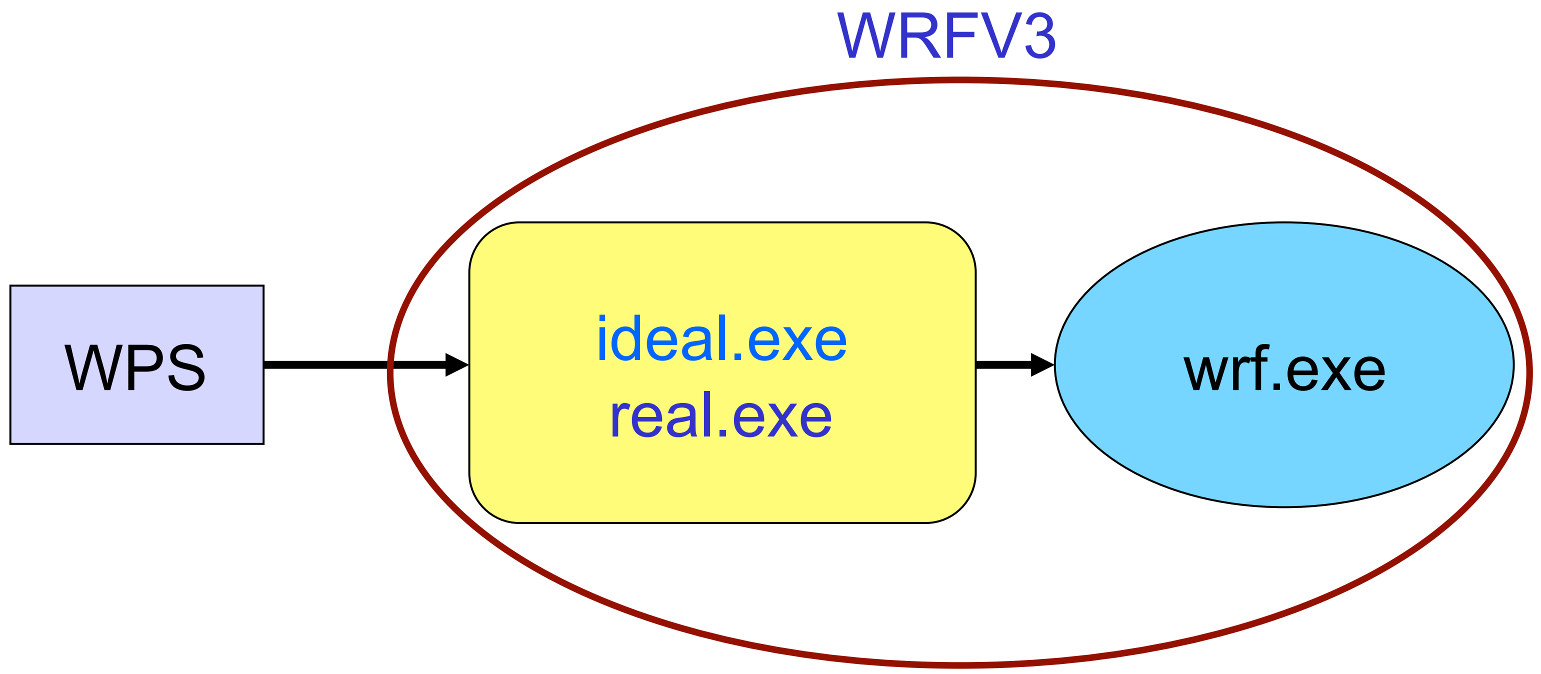
WRF System Flowchart



Outline

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

Before You Run ..

- Check and make sure appropriate executables are created in **`WRFV3/main/`** directory:

  For ARW:
  - **`ideal.exe`**
  - **`real.exe`**
  - **`wrf.exe`**
  - **`ndown.exe`**
  - **`tc.exe`**

  *Built with '**`em_real`**'*

- If you are running a real-data case, be sure that files for ***a few time periods*** from WPS are correctly generated:
  - **`met_em.d01.*`**
- Prepare **`namelist.input`** for runtime options.

WRF test case directories

You have these choices in **`WRFV3/test/`**

(made at compile time):

- **`em_real`** } 3d real-data
- **`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

} *ARW:* **`real.exe`** / **`ideal.exe`** **`wrf.exe`**

Steps to Run

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

WRFV3/run directory

```
README.namelist
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
ETAMPNEW_DATA
tr49t67
tr49t85
tr67t85
gribmap.txt
grib2map.tbl
```

…. (a few more)

these files are model physics data files: they are used to either initialize physics variables, or make physics computation more efficient

WRFV3/run directory after compile

```
LANDUSE.TBL
SOILPARM.TBL
VEGPARM.TBL
GENPARM.TBL
URBPARM.TBL
RRTM_DATA
RRTMG_SW_DATA
RRTMG_LW_DATA
ETAMPNEW_DATA
tr49t67
tr49t85
tr67t85
…
namelist.input   -> ../test/em_real/namelist.input
real.exe -> ../main/real.exe
wrf.exe -> ../main/wrf.exe
ndown.exe -> ../main/ndown.exe
```

…. (a few more)

An example after ARW real case compile

Running an Idealized Case

(See talk on ‘Idealized Cases’ on Tues)

Running an *Idealized* Case

- If you have compiled an ideal case, you should have:

  `ideal.exe` - ideal case initialization program

  `wrf.exe` - model executable

- These executables are linked to:

  `WRFV3/run`

  and

  `WRFV3/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 a subset of physics data files to the currect 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 conditions are set in the **`namelist.input`** file. For example, these are for options in east-west, or x direction:

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

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 (where ***N*** is the number of processors requested)

- Successful running of the model executable will create a model history file called `wrfout_d01_<date>`

  $$\texttt{e.g. wrfout\_d01\_}\underbrace{\texttt{0001-01-01\_00:00:00}}_{\textit{Based on start date set in namelist}}$$

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. *(see talk on Tues)*

***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

Running ARW Real-Data Case

Running ARW 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:

  `WRFV3/run`

  and

  `WRFV3/test/em_real`

➔ One can go to either directory to run.

WRFV3/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
ETAMPNEW_DATA -> ../../run/ETAMPNEW_DATA
tr49t67 -> ../../run/tr49t67
tr49t85 -> ../../run/tr49t85
tr67t85 -> ../../run/tr67t85
…
namelist.input           - editing required
real.exe -> ../../main/real.exe
wrf.exe -> ../../main/wrf.exe
ndown.exe -> ../../main/ndown.exe
```

…. (a few more)

Running WRF ARW Real-data Cases

- One must successfully run WPS, and create **`met_em.*`** file for more than one time period – check output after running WPS

- Link or copy WPS output files to the run directory:

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

Running WRF ARW Real-data Cases

- 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,
```
or
```
 mpirun -machinefile file -np N ./real.exe
```
for a MPI job

where ***N*** is the number of processors requested, and ***file*** has a list of CPUs for the MPI job

Running WRF ARW Real-data Cases

- Successfully running this program will create model initial and boundary files:

```
wrfinput_d01
wrfbdy_d01
```

Single time level data at model's start time

N-1 time-level data at the lateral boundary, and only for domain 1

The boundary file contains the values at the start of a bdy time and tendencies during the bdy interval

N: the number of time periods processed

Running WRF ARW Real-data Cases

- 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:

$$\texttt{wrfout\_d01\_20}\underbrace{\texttt{05-08-28\_00:00:00}}_{\textit{Based on start date set in namelist}}$$

and a *restart* file if **`restart_interval`** is set to a time within the range of the forecast time:

```
wrfrst_d01_2008-08-28_12:00:00
```

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

&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,
frame_per_outfile       = 1000, 1000, 1000,
restart_interval        = 360,
restart                 = .false.,
```

domain 1 option

nest options

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
  - 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`

- *frame_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 that is 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 *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 times to restart times in namelist

&time_control

```
io_form_history      = 2,
io_form_restart      = 2,
io_form_input        = 2,
io_form_boundary     = 2,
debug_level          = 0,
```

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

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

Debug print control: Increasing values give more prints.

&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                   = 28,    28,    28,
num_metgrid_levels       = 21
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.
  - ARW: 6xDX (DX is grid distance in km): for DX=10km, time_step = 60
- *e_we, e_sn, e_vert*:
  - Model grid dimensions (staggered) in X, Y and Z directions.
- *num_metgrid_levels*:
  - Number of *metgrid* (input) data levels.
- *num_metgrid_soil_levels*:
  - Number of soil data levels in the input data

  Found by typing `ncdump -h met_*.d01.<date> | more`
- *dx, dy*:
  - grid distances: in meters for ARW.

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 Ptop)

- *eta_levels*:
  - Specify your own model levels from 1.0 to 0.0.
  - If not specified, program *real* will calculate a set of levels

Where do I start?

- Always start with a *namelist* template provided in a test case directory, whether it is an ideal case, or 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 p 5-25 to 5-27 of the User's Guide:
  - 2 or 4 km convection-permitting runs
  - 20 – 30 km, 2 – 3 day runs
  - Antarctic region
  - Tropical storm forecasting
  - Regional climate

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 (ARW), and registry.io_boilerplate (IO options, shared)

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` or `ncBrowse` (great tools!)
- Use post-processing tools (see talks later)

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

- ~~A print of namelist options~~ file: *namelist.output*
- Time taken to compute one model step:

```
Timing for main: time 2000-01-24_12:03:00 on domain   1:    3.25000 elapsed seconds.
Timing for main: time 2000-01-24_12:06:00 on domain   1:    1.50000 elapsed seconds.
Timing for main: time 2000-01-24_12:09:00 on domain   1:    1.50000 elapsed seconds.
Timing for main: time 2000-01-24_12:12:00 on domain   1:    1.55000 elapsed seconds.
```

- Time taken to write history and restart file:

```
Timing for Writing wrfout_d01_2000-01-24_18:00:00 for domain   1:   0.14000 elapsed seconds.
```

- Any model error prints: (example from ARW run)

```
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)`
  - ➢ Memory error. 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 lots of

```
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 ARW User's Guide, Chapter 5
- Also see '*Nesting Setup and Run*' and *'Other Runtime Options'* talks.