Set Up and Run WRF

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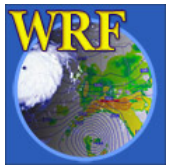
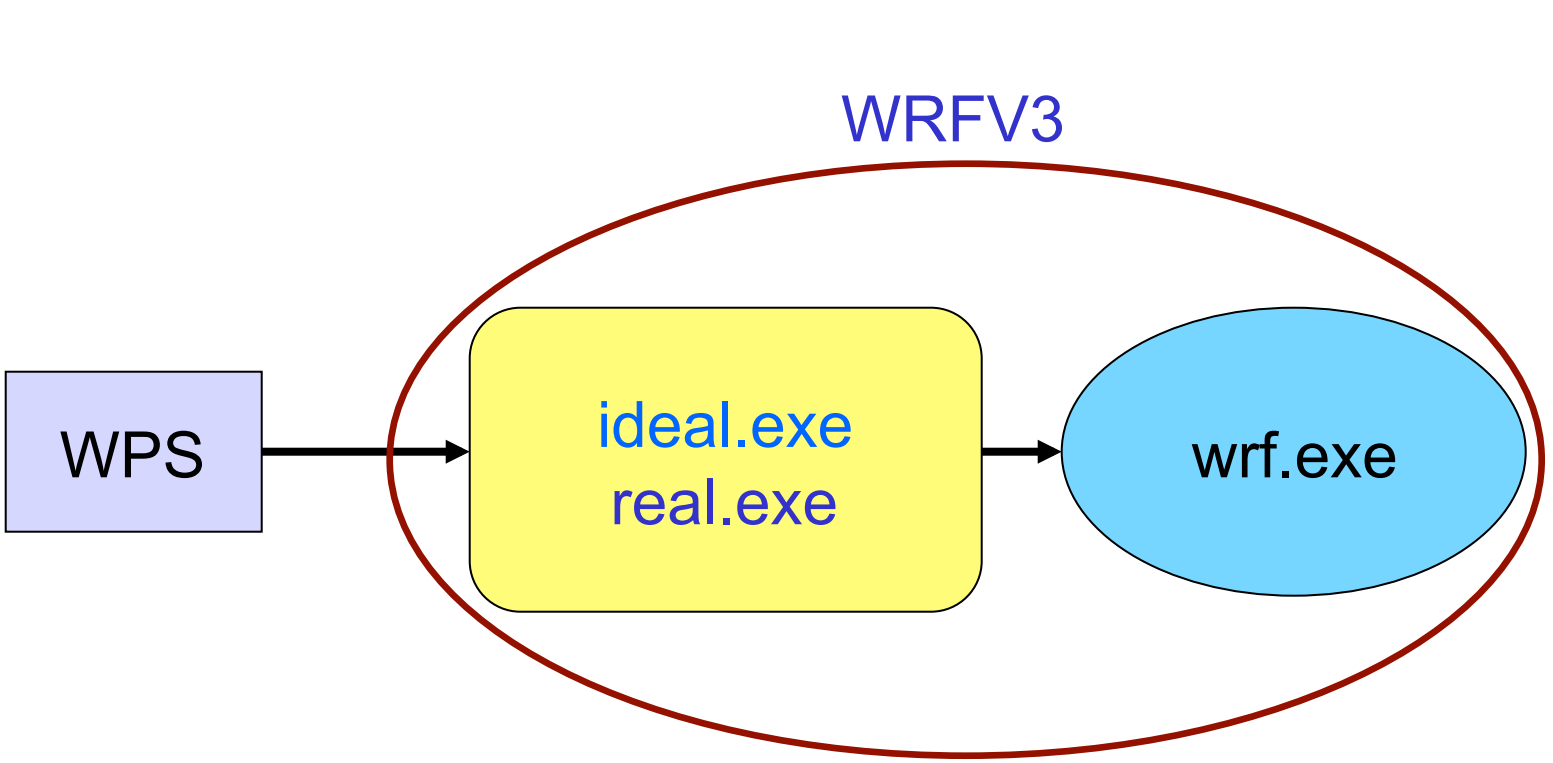


WRF System Flowchart



Outline

- Running WRF code
  - Before you run..
  - Running a real-data case
  - Running an idealized 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:
  - **`real.exe`**
  - **`wrf.exe`**
  - **`ndown.exe`**
  - **`tc.exe`**
- If you are running a real-data case, be sure that files from WPS are correctly generated:
  - **`met_em.d01.*,`** for ARW
- Prepare **`namelist.input`** for runtime options.

WRF test case directories

There are these test cases in **`WRFV3/test/`**

(made at compile time):

- **`em_real`** } 3d real-data < *real.exe*, *wrf.exe*
- **`em_quarter_ss`**
- **`em_b_wave`**
- **`em_les`**
- **`em_heldsuarez`**
- **`em_tropical_cyclone`**

  } 3d ideal

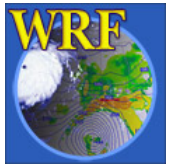
- **`em_hill2d_x`**
- **`em_squall2d_x`**
- **`em_squall2d_y`**
- **`em_grav2d_x`**
- **`em_seabreeze2d_x`**

  } 2d ideal

- **`em_scm_xy`**

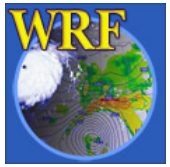
  } 1d ideal

} *ideal.exe*, *wrf.exe*



Steps to Run

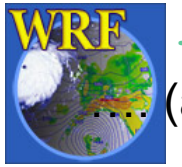
1. cd to *run/* or one of the *test case* directories
2. Link or move WPS output files to the directory for real-data cases
3. Edit *namelist.input* file for the appropriate grid and times of the case
4. Run initialization program, *real.exe*
5. Run model executable, *wrf.exe*



WRFV3/run directory

README.namelist
LANDUSE.TBL
GENPARM.TBL
SOILPARM.TBL
VEGPARM.TBL
URBAN_PARAM.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
… (a few more)

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

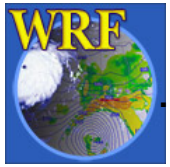


WRFV3/run directory after compile

```
LANDUSE.TBL
ETAMPNEW_DATA
GENPARM.TBL
RRTM_DATA
RRTMG_SW_DATA
RRTMG_LW_DATA
SOILPARM.TBL
VEGPARM.TBL
URBAN_PARAM.TBL
tr49t67
tr49t85
tr67t85
gribmap.txt
grib2map.tbl
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 real case compile



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:

  `WRFV3/run`

  and

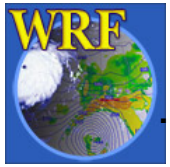
  `WRFV3/test/em_real`

➔ One can go to either directory to run.

WRFV3/test/em_*real* directory

```
LANDUSE.TBL -> ../../run/LANDUSE.TBL
ETAMPNEW_DATA -> ../../run/ETAMPNEW_DATA
GENPARM.TBL -> ../../run/GENPARM.TBL
RRTM_DATA -> ../../run/RRTM_DATA
RRTMG_SW_DATA -> ../../run/RRTMG_SW_DATA
RRTMG_LW_DATA -> ../../run/RRTMG_LW_DATA
SOILPARM.TBL -> ../../run/SOILPARM.TBL
VEGPARM.TBL -> ../../run/VEGPARM.TBL
URBAN_PARAM.TBL -> ../../run/URBAN_PARAM.TBL
tr49t67 -> ../../run/tr49t67
tr49t85 -> ../../run/tr49t85
tr67t85 -> ../../run/tr67t85
gribmap.txt -> ../../run/gribmap.txt
grib2map.tbl -> ../../run/grib2map.tbl
namelist.input                - require editing
real.exe -> ../../main/real.exe
wrf.exe -> ../../main/wrf.exe
ndown.exe -> ../../main/ndown.exe
```

… (a few more)

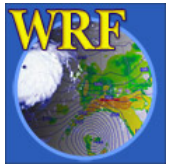


Running a Real-data Case

- One must successfully run WPS, and create **met_em.*** file for more than one time period

- Link (or move) WPS 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:

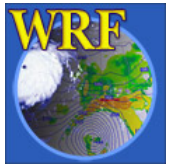
  `./real.exe`, if compiled serially / SMP, or

  `mpirun -np N ./real.exe`, or

  `mpirun -machinefile file -np N ./real.exe`

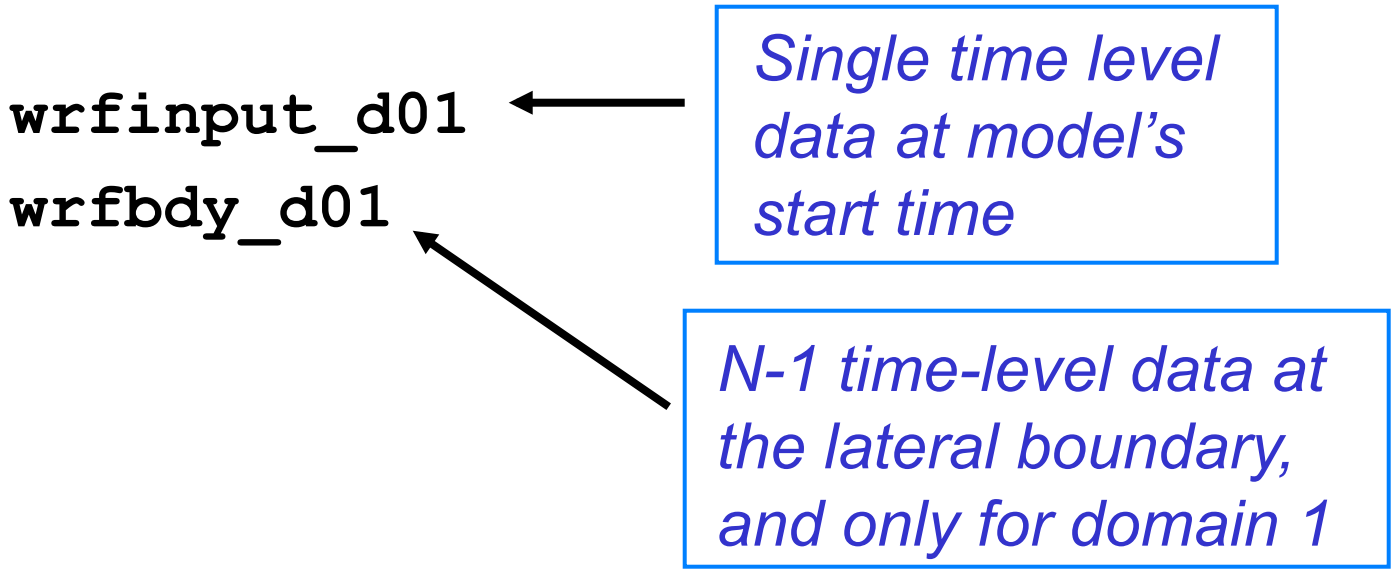
  for a MPI job

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



Running a Real-data Case

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



N: the number of time periods processed

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 create a model *history* file (one or more output times):

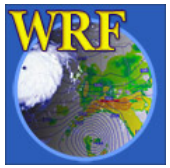
  `wrfout_d01_2005-08-28_00:00:00`

  Based on the start date in namelist

And *restart* file if **`restart_interval`** is set to a time within the range of the forecast time (single time):

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

Running an Idealized Case



Running an Idealized Case

- If you have compiled the an idealized case, you should have:

  `ideal.exe` – ideal data 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.

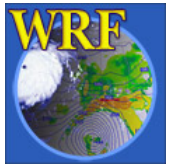
Running an Idealized Case

- Do not need to run WPS: initial condition typically defined by a sounding, or a 2-D file (e.g. *input_jet* for b_wave case)
- To link physics tables, run the script in the case directory:

  run_me_first.csh
- To run the initialization program, type

  `./ideal.exe`
- To run the model executable,

  `./wrf.exe`



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

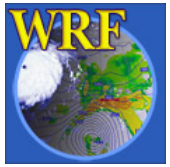
  Single column: value valid for all domains

&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                             = .true.,
```

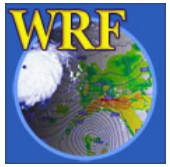
First column: domain 1 option

nest options



Notes on `&time_control`

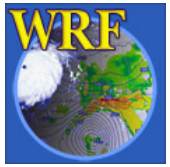
- *run_** time variables:
  - Model simulation length: *wrf.exe* and domain 1 only
- *start_** and *end_** time variables:
  - Program *real* will use WPS output between these times to produce lateral (and lower) boundary file
  - They can also be used to specify the start and end of simulation times 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 LBC 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

&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

Useful alternative:

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

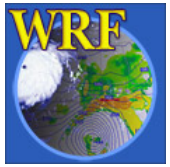
Debug print control: Increasing values give more prints.

&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,
```

Match the dimensions defined in WPS

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.
  - 6xDX (DX is grid distance in km)
  - May be divided by output intervals
- *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
- *dx, dy*:
  - grid distances: 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.

- *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

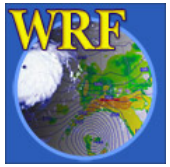
    namelist.input.4km ~ 4 km grid size

    namelist.input.jun01 ~ 10 km grid size

    namelist.input.jan00 ~ 30 km grid size
  - Examples of namelists for various applications, Chapter 5 of the User's Guide

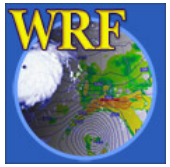
Where do I start?

- 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, and registry.io_boilerplate (IO options)

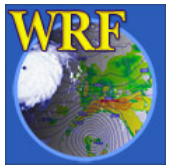


To run a job in a different directory..

- 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, namelist and executables, and you should be able to run a job anywhere on your system.



Check Output



Output from a Model Run

- Standard out/error files:

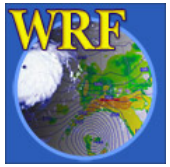
  `wrf.out`, or **`rsl`**.* files

- 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**:

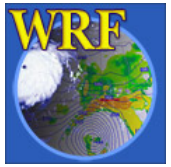
  ncdump -v Times wrfout_d01_<date>

  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?

- 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.
```

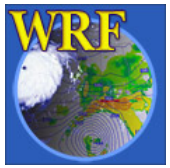
- Time taken to write history and restart file:

```
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

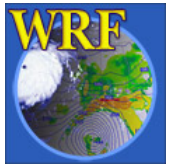


Simple Trouble Shooting

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

- More are added since V3.2 to help one to correct namelist setup errors.



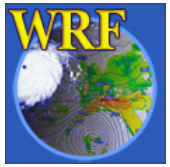
Often-seen Runtime Problems

- `Segmentation fault (core dumped)`
  - Often typing **'unlimit'** or **'ulimit -s unlimited'** can help if this happens immediately after the start.

- 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 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 Setup and Run*' and *'Other Runtime Options'* talks.