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

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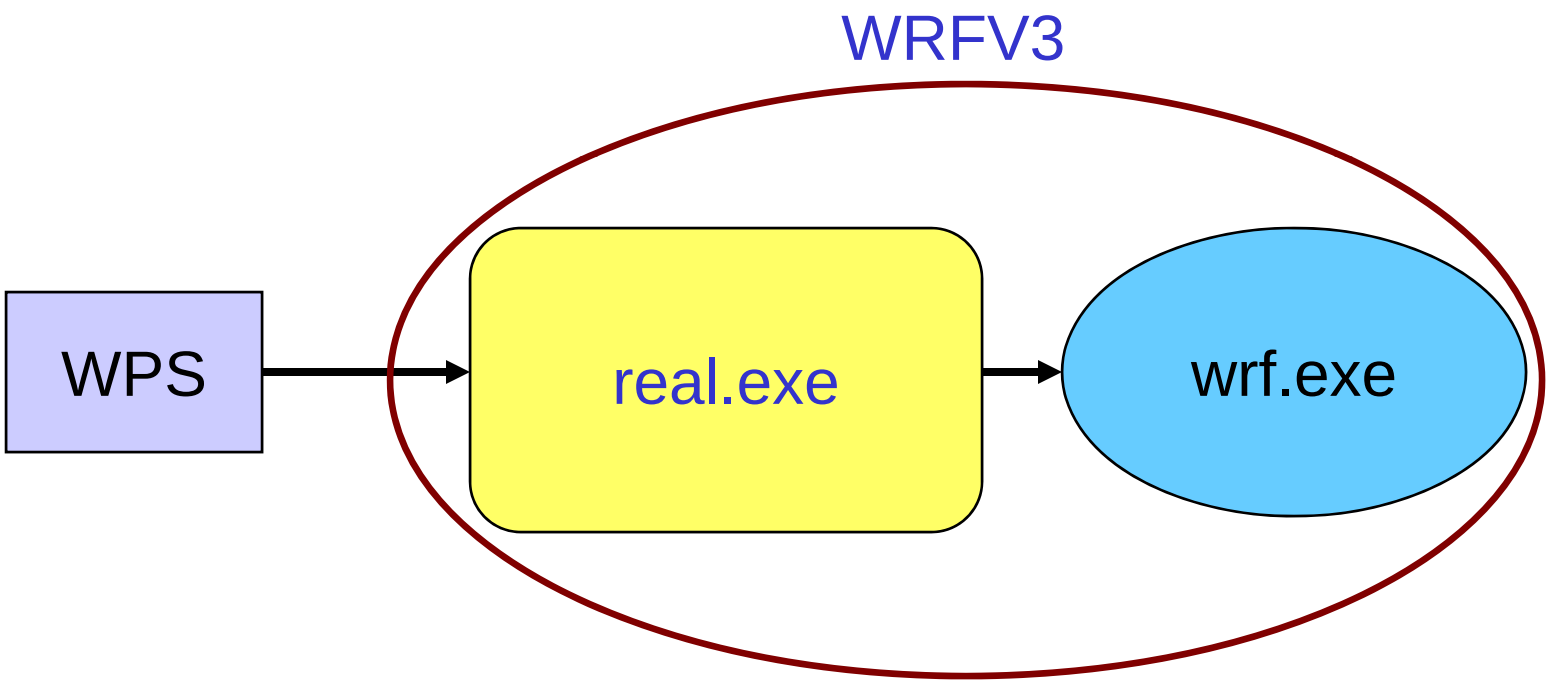
# WRF System Flowchart



# Outline

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

*This talk is complementary to 'Nesting' talk later.*

# Before You Run ..

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

  For ARW:

  - **`real.exe`**
  - **`wrf.exe`**
  - **`ndown.exe`**
  - **`tc.exe`**

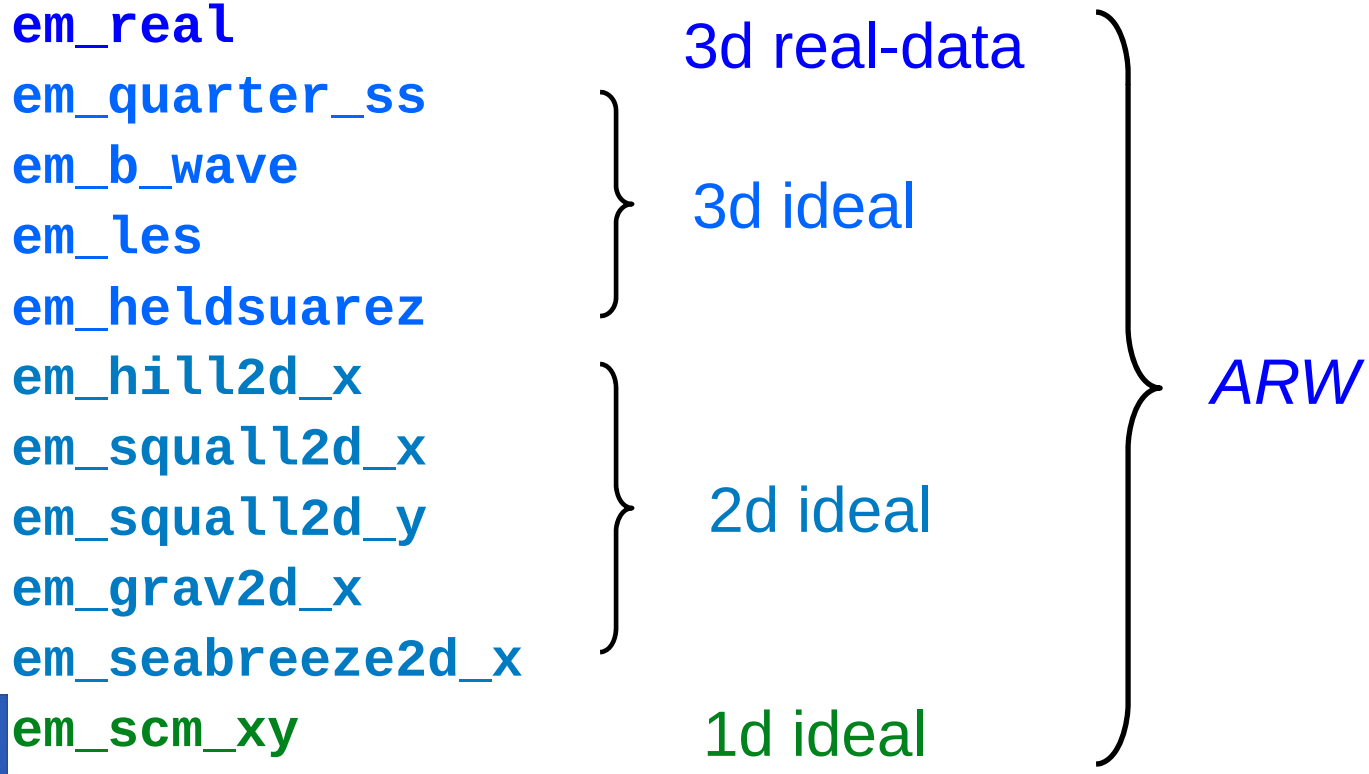
- If you are running a real-data case, check that files from WPS are correctly generated:
  - **`met_em.d01.*`**


- Prepare **`namelist.input`** for runtime options.

# WRF test case directories

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

(made at compile time):



# 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, *real.exe*
5. Run model executable, *wrf.exe*

# WRFV3/run directory

**README.namelist**
**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**
…. (a few more)

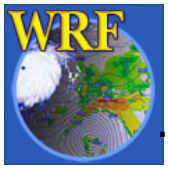
*these files are model physics data files: they are used to either initialize physics variables, or make physics computation more efficient*

# 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 ARW real case compile*



# 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 into:

  **`WRFV3/run`**

  and

  **`WRFV3/test/em_real`**


➔ One can go to either directory to run a forecast.

# 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                - requires editing
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 for regional forecasts

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

```
cd test/em_real
ln -sf ../../../WPS/met_em.d0?.* .
```

# 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

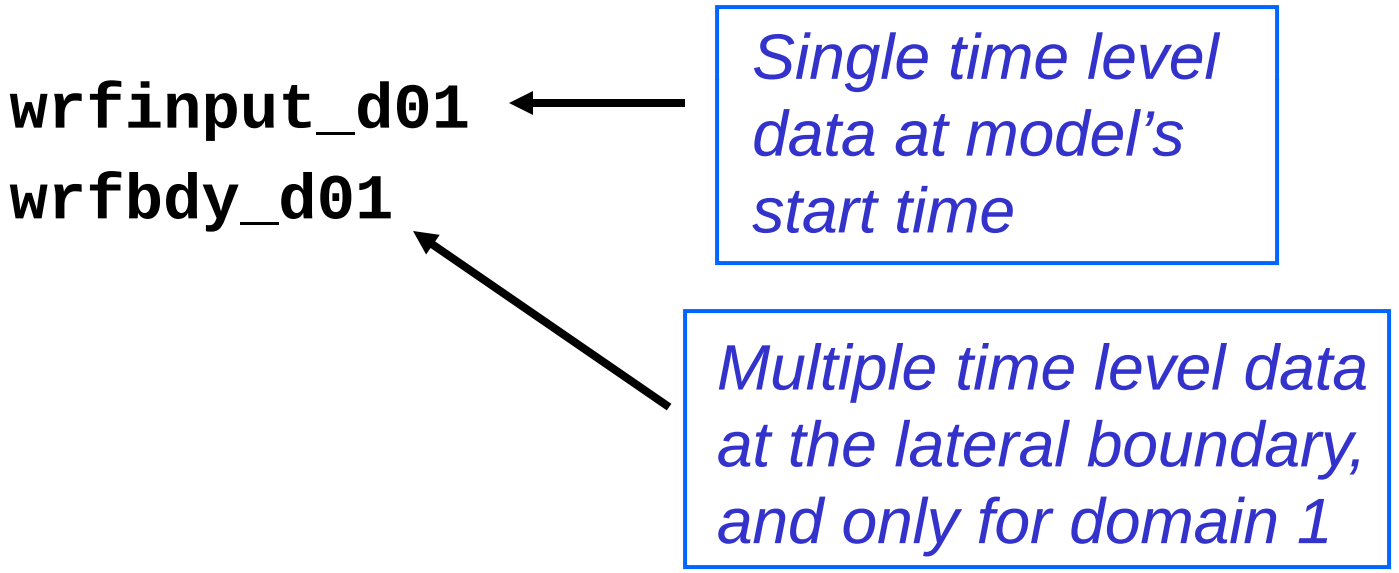
  **`mpirun -np N ./real.exe`**

  for an MPI job

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

# Running WRF ARW Real-data Cases

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



# Running WRF ARW Real-data Cases

- Run the model executable by typing:

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

  or

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

- Get in the habit of removing the rsl* files between parallel runs, as the results are othereise difficult to interpret

# Running WRF ARW Real-data Cases

- Successfully running the model will a create model *history* file (such as):

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

  And *restart* file if **`restart_interval`** is set to a time within the range of the forecast time (12-h):

  **`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 of a namelist record

  **`/`** - end of a namelist record

- As a general rule for the WRF system:

  Multiple columns: the variable is 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,
```

domain 1 option, or option for all domains

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 files
  - These variables *may* be used to specify the start and end of simulation times for the coarse grid.
  - They define the start and end time for all fine grid domains.

# Notes on **`&time_control`**

- *interval_seconds*:
  - Time interval between WPS output times, which then becomes the LBC update frequency
- *history_interval*:
  - Time interval (in minutes by default) when a WRF model 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 (allows a forecast restart to be done later).
  - The 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`**

# &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

**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 - leave it at zero unless debugging.

# &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 (CG only).
  - Fractional time step specified in separate integers of numerator and denominator.
  - ARW: 6 x DX (DX = grid distance (km), 15 km => 90 s dt)
- *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* either specify:
  - your own model levels from 1.0 to 0.0, OR,
  - If not specified, program *real* will calculate a set of levels for you based on the number of vertical levels

# Where do I start?

- Always start with a *namelist* template provided in a test case directory.
  - 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?

- Use documention to guide the modification of the namelist values:
  - run/README.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 (ARW), registry.io_boilerplate (IO options)

# To run a job in a different directory..

- Directories *run/* and test_em_real/ are convenient places to run, but it is not required.
- Copy or link the content of these directories to another directory, including physics data files, wrf input and boundary files and 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`** (serial) or **`rsl`**.* (from MPI)

- 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 computational 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`**

*Master node has domain-wide info*

You should see the following if the job has 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** for non-diagnostic graphics

# What is in a *wrf.out* or *rsl.out.0000* 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.
```

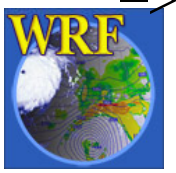
- Time taken to write history and restart file:

```
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

# Often-seen runtime problems

- `Segmentation fault (core dumped)`
  - Often typing **‘unlimit’** or
    **‘ulimit -s unlimited’** or equivalent can help when this happens immediately after the run starts

# Often-seen runtime problems

- `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
    - > search for info in model out/err print files
    - > 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