WRF Nesting: 
Set Up and Run

Wei Wang 
NCAR/MMM 
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Outline

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• Running WRF with nests
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Before You Run ..

• Make sure you have selected basic nest compile options and appropriate executables are created in WRFV3/main/ directory:
  - real.exe – executable to create IC/BC
  - wrf.exe – executable for model integration
  - ndown.exe – utility program for one-way nesting
  - tc.exe – utility program for TC bogusing

• If you are working with real data, be sure that files for nest domains from WPS are generated:
  - met_em.d01.<date>, met_em.d0*.<date> (terrain, static land data are in the nested files)

Steps to Run (same as before)

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 and times of the case
4. Run initialization program, real.exe
5. Run model executable, wrf.exe
All in the namelist...

- Nearly all controls for a nested run can be achieved by editing the namelist file.
- Nest-specific namelist options will be explained next.

Important to note:
- Key variable: `max_dom` must be set to $\geq 2$
- Need to pay attention to multi-column namelists

Nest namelist Options

**&time_control**

- `interval_seconds` = 21600
- `history_interval` = 180, 60, 60
- `frames_per_outfile` = 1000, 1000, 1000
- `restart_interval` = 360

These control the start and end times of the nests. They can be different from the parent domain, but must fit in the time window of the parent domain.

History output may be split into multiple files.

- History files are written one for each domain
- History intervals may be different for different domains
- Restart files are also written one per domain
&time_control

Nest input option:

- `input_from_file = .true., .true., .true.,`
- `fine_input_stream = 0, 2, 2,`

Specify what fields to use in nest input: they can be all (0), or data specified in I/O stream 2 in Registry (2). **Limited use:** if a nest starts at a later time, or have an updated analysis only on domain 1.

Whether to produce in `real.exe` and use nest wrfinput files in `wrf.exe`. This is usually the case for real-data runs. For idealized nest runs, set it to `.false.`.

nml record &domains

- `max_dom = 3,`
- `e_we = 74, 112,94,`
- `e_sn = 61, 97, 91,`
- `e_vert = 30, 30, 30,`
- `grid_id = 1, 2, 3,`
- `parent_id = 0, 1, 2,`
- `i_parent_start = 0, 31, 30,`
- `j_parent_start = 0, 17, 30,`

Activate nests: no. of domains to run

Dimensions of all domains; same as in WPS.

- `dx = 30000., 10000., 3333.33,`
- `dy = 30000., 10000., 3333.33,`
- `parent_grid_ratio = 1, 3, 3,`
- `parent_time_step_ratio = 1, 3, 3,`

For fractional grid distance, use at least 2 decimal places

- All 4 variables must be specified.
- **Grid ratio** can be any integer (3 and 5 are recommended), and **time step ratio** can be different from grid ratio.
- Grid distance is in meters, even for lat/lon map projection.

&domains

- `feedback = 1,`
- `smooth_option = 2,`

When feedback is on, this option can be selected to smooth the area in the parent domain where the nest is. Valid values are 0,1,2.

Whether a nest will overwrite parent domain results. Setting feedback=0 ‘one-way’ nesting in a concurrent run.
namelist record &bdy_control

\begin{align*}
\text{spec\_bdy\_width} & = 5, \quad (10) \\
\text{spec\_zone} & = 1, \\
\text{relax\_zone} & = 4, \quad (9) \\
\text{specified} & = .T.,.F.,.F., \\
\text{nested} & = .F.,.T.,.T.,
\end{align*}

Boundary condition option for domain 1.

Boundary condition option for nests.

May change \text{relax\_zone} and \text{spec\_bdy\_width} \quad (\text{spec\_zone} + \text{relax\_zone} = \text{spec\_bdy\_width})

\* Wider boundary zone may work better for coarser driving data

Other notes on namelists

- Use same physics options for all domains.
  - An exception is cumulus scheme. One may need to turn it off for a nest that has grid distance of a few kilometers.
- Also use same physics calling frequency (e.g. radt, cudt, etc.) in all domains.

Where do I start?

- Always start with a \textit{namelist} template provided in a test case directory, whether it is a ideal case, or real data case.
- Not all namelists are function of domains. If in doubt, check Registry.EM_COMMON and registry.io_boilerplate (look for string ‘namelist’).
- Use document to guide the modification of the namelist values:
  - run/README.namelist
  - User’ s Guide, Chapter 5

Running Nested Case
Running a Nested Case

- Files available from WPS:
  - `met_em.d01.<date>` (a few time periods)
  - `met_em.d02.<date>` (at least one time period data)
  (* terrain, static land data are in the nested files)
- Move or link WPS output files to the run directory:
  - `cd test/em_real`
  - `ln -s ../../../WPS/met_em.* .`

Running a Nested Case

- Edit `namelist.input` file for runtime options (set `max_dom >= 2` in `&domains` for a nested run)
- 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 Nested Case

- Successfully running this program will create model initial and boundary files:
  - `wrfinput_d01`
  - `wrfinput_d02`
  - `...`
  - `wrfbdy_d01`

  **Single time level data at model’s start time for all domains**

  **Multiple time-level data at the lateral boundary, for domain 1 only**

Running a Nested Case

- Run the model executable by typing:
  - `./wrf.exe >& wrf.out &`
  - or `mpirun -np N ./wrf.exe &`
- Successfully running the model will create model history files, one for each domain:
  - `wrfout_d01_2005-08-28_00:00:00`
  - `wrfout_d02_2005-08-28_00:00:00`

  And *restart* file if `restart_interval` is smaller than the integration time:
  - `wrfrst_d01_<date>`, `wrfrst_d02_<date>`
Moving Nest Case

- The main reason for using this option is to run the model economically.
- Must choose correct compile options when creating `configure.wrf` file
  - Choose `preset move`, or `vortex following`
- Other options are controlled by the namelists.
- Can do specified move, and automatic vortex tracking (for tropical cyclone application).
- All nest domains can move, but driven by the innermost nest.

Specified Moving Case

- namelists in `&domains`:
  
  - `num_moves`, `move_id`, `move_interval`, `move_cd_x`, `move_cd_y`
  - nest can only move one parent-grid-cell at a time.
    - i.e., `move_cd_x = 1, -1, or 0`
- Also specify initial nest location:
  
  - `i_parent_start, j_parent_start`

Automatic Moving Case

- Tropical cyclone applications only.
- Works better for well developed storms.
- Namelists in `&domains`:
  
  - `vortex_interval` (default 15 min)
  - `max_vortex_speed` (default 40 m/s)
  - `corral_dist` (default 8 coarse grid cells)
  - `track_level` (default 50000 Pa)
  - `time_to_move` (default is 0 h for all nests)
- Also specify initial nest location
  
  - `i_parent_start, j_parent_start`

One-way Nesting: Two separate runs

*Less common option:*

- Prepare data as if one were to run a two-way nested case up to program real:
- Run WRF model for coarsest domain first. Should output model frequently (e.g. hourly);
- Use program `ndown.exe`, together with coarse/parent domain model output and nest domain `wrfinput` file, to generate `wrfinput` and `wrfbdy` file for the next model run;
- Run WRF model for the second domain.
  
  (Also see Chapter 5, pages 15 - 19)
## Summary

- Two-way, without nest input files
  \( \text{input\_from\_file=}f.; \text{feedback} = 1 \)
- Two-way, with nest input files
  \( \text{input\_from\_file=}t.; \text{feedback} = 1 \)
- Two-way, with static nest input only
  \( \text{input\_from\_file=}t., \text{fine\_input\_stream}=2 \)
- One-way, \textit{concurrent} run (\text{feedback} = 0)
- One-way, \textit{separate} runs (treated like two single-domain runs, with \textit{ndown})
- Two-way, specified moving nest run
- Two-way, automatic vortex tracking run

## Notes about Nesting

- **When should I use nests?**
  - Input data resolution is too coarse (for example, some reanalysis data: NNRP, NCEP2, climate model data)
  - Would like to simulate localized convection, topography- and/or landuse-forced phenomena, etc.
  - Would like to provide better boundary conditions for the area of interest: boundary conditions from external sources are typically 3 – 6 hourly, while nested boundary conditions are in minutes (coarse domain time step)
  - There isn’t sufficient computing resources

- **Nest domain sizes should not be too small:**
  - No less than 100x100
  - Avoid boundary zones which are about 10 grid point wide
  - Avoid ‘sweeping’ effect from lateral boundaries
  - Avoid placing nest boundaries over high mountains

## References

- Information on compiling and running WRF with nests, and a more extensive list of namelist options and their definition/explanation can be found in the \textbf{User’s Guide, Chapter 5}
- Start with namelist templates in \textit{test/} directory, and refer to namelist used for different applications on pages 5-33 – 35 in the User’s Guide
- Practice with online tutorial, and in the class.