NESTING IN WRF

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What is a nest?

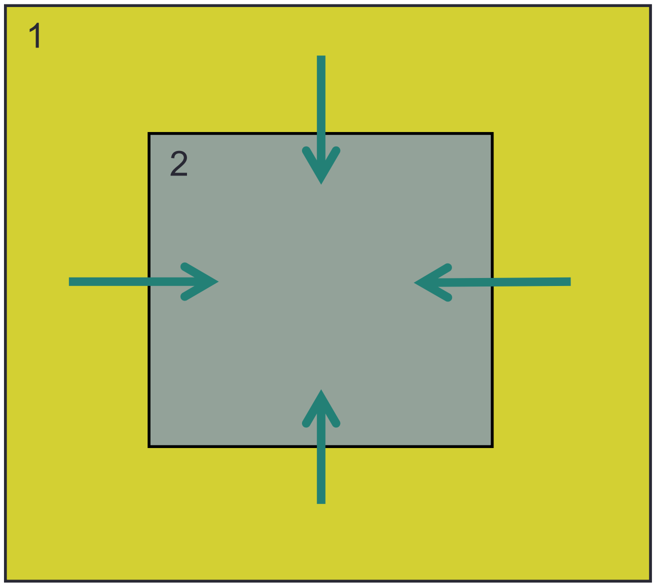
- A *finer-resolution* domain embedded in a coarser resolution domain, and run together with the coarser resolution domain

- Most input data are on the order of about 1 degree or ½ a degree – You don't want to interpolate down to, say a 3 km domain from 1 degree.

- Enables running at a higher-resolution without uniformly high-resolution over a large domain – VERY expensive

What is a nest?

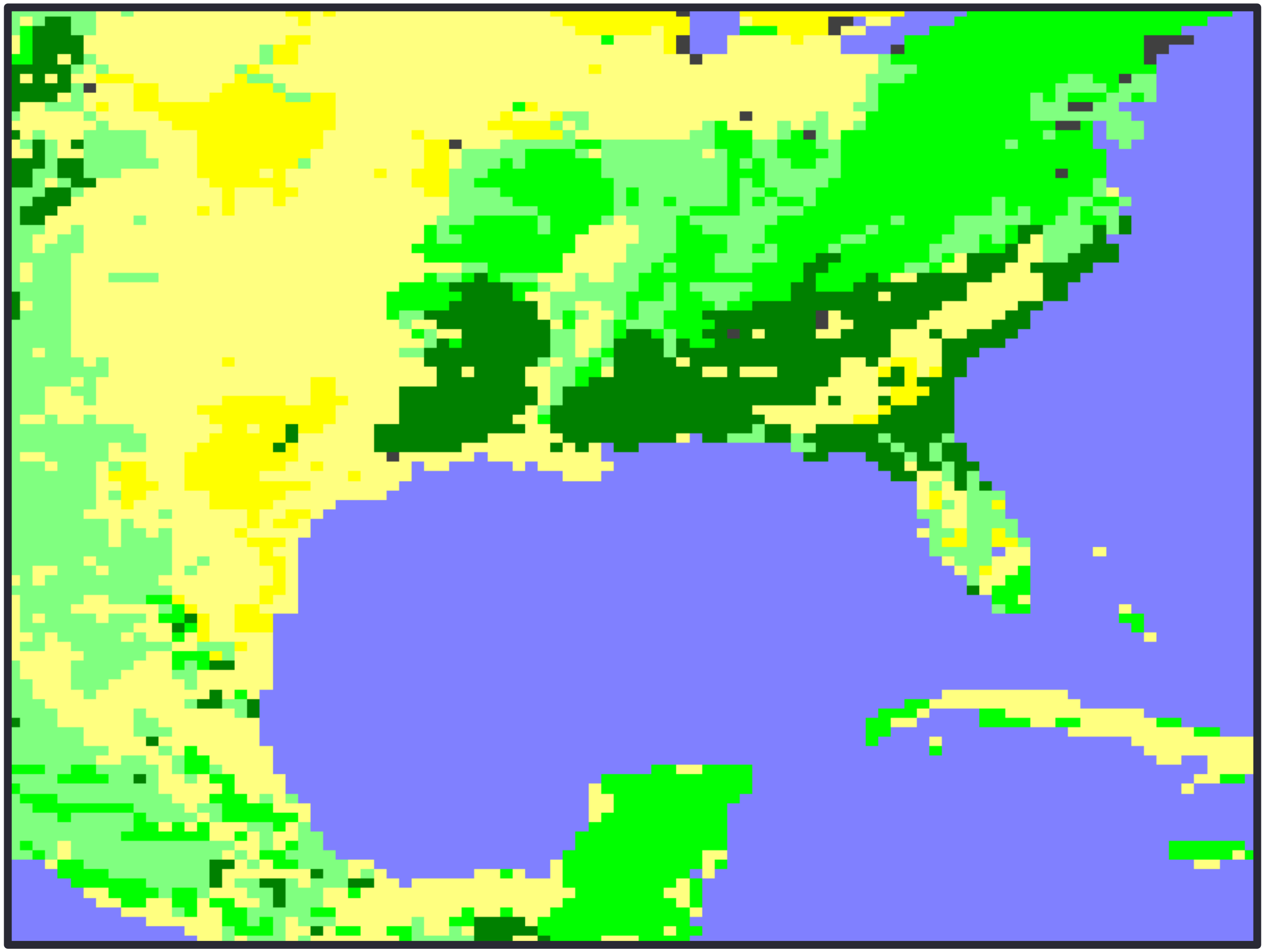
- Covers a portion of the parent domain, and is fully contained by the parent domain
- Driven along its lateral boundaries by the parent domain
- May feedback the computed values back to the parent domain



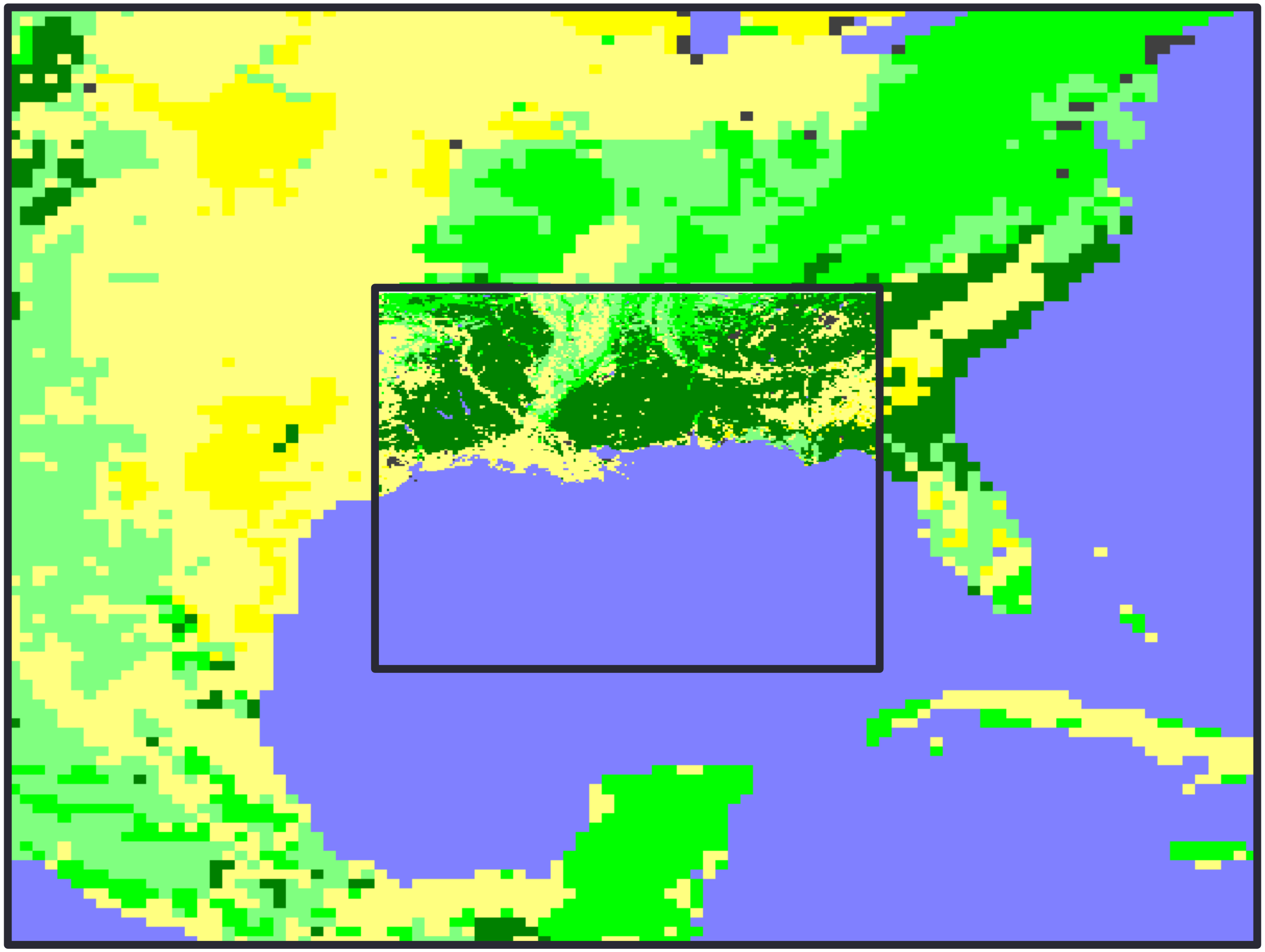
When Should I Use Nests?

- Need to simulate localized phenomena: convection, topography, landuse-forced, etc.
  - What resolution is necessary to resolve what you are interested in?
  - Input data resolution is too coarse by more than a factor of 5-10x
  - Computing resources not available for uniform coverage

Coarse Domain



Higher-resolution Embedded Nest



Types of Nesting

- Using a single input domain (met_em.d01*)
  - No met_em.d02* files are used
  - All fields are interpolated from the model coarse grid
  - Only recommended if nest is over the ocean

- Using multiple input domains
  - Each domain contains full input data files (including topography, landuse, etc.)

- Specified move
  - Build WRF with “2=preset moves”
  - Must specify every move
  - Can use, but tedious to set-up

- Automatic move
  - Build WRF with “3=vortex following”
  - Only for tropical cyclone tracking
  - Expensive for single large nest

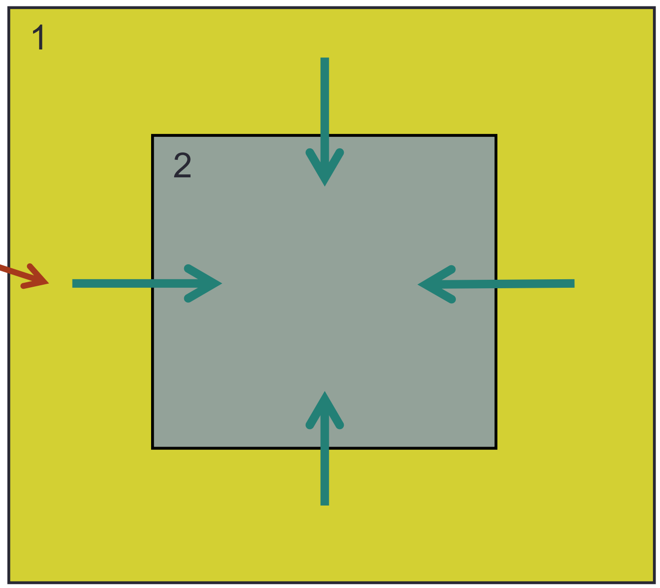
- ndown.exe
  - Use coarser WRF model output to drive finer resolution domains (i.e. ‘downscaling’)
  - If you have run a long coarse domain simulation (years) and later decide you want to have a nest with higher resolution.

Types of Nesting

One-way/two-way nesting

- Determined by the namelist parameter “feedback”
  - **feedback = 0 (turned off/one-way)**

Lateral boundary conditions are fed to the nest, from the parent.



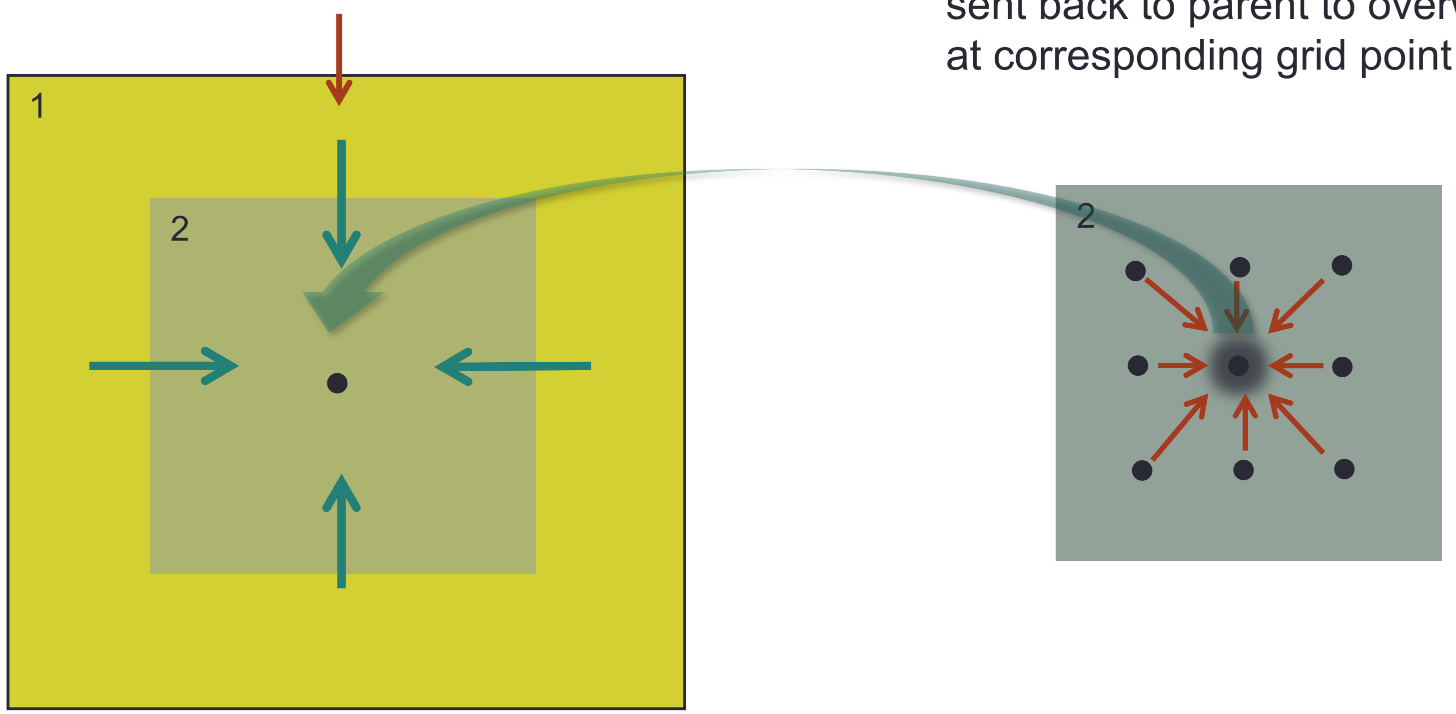
Types of Nesting

One-way/**two-way nesting**

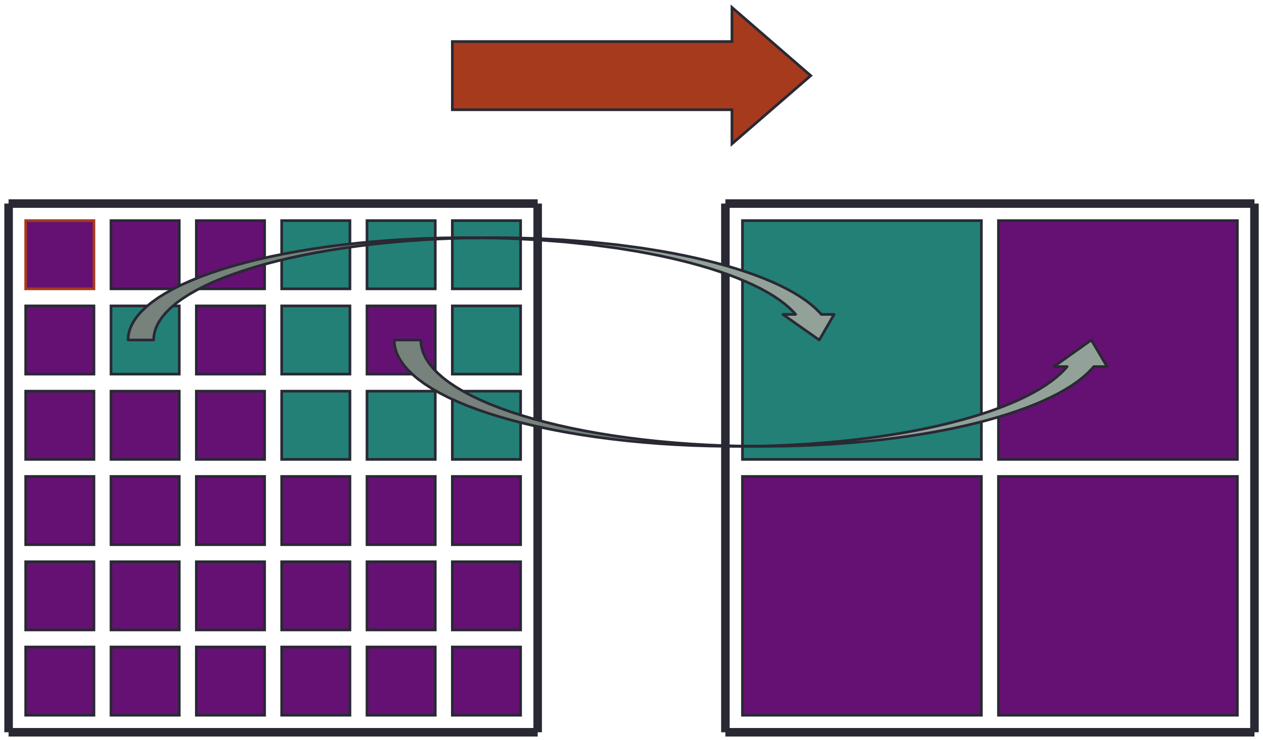
- Determined by the namelist parameter “feedback”
  - **feedback = 1 (turned on/two-way)**

(1) Lateral boundary conditions are fed to the nest, from the parent.

(2) Child values are averaged, and then sent back to parent to overwrite value at corresponding grid point

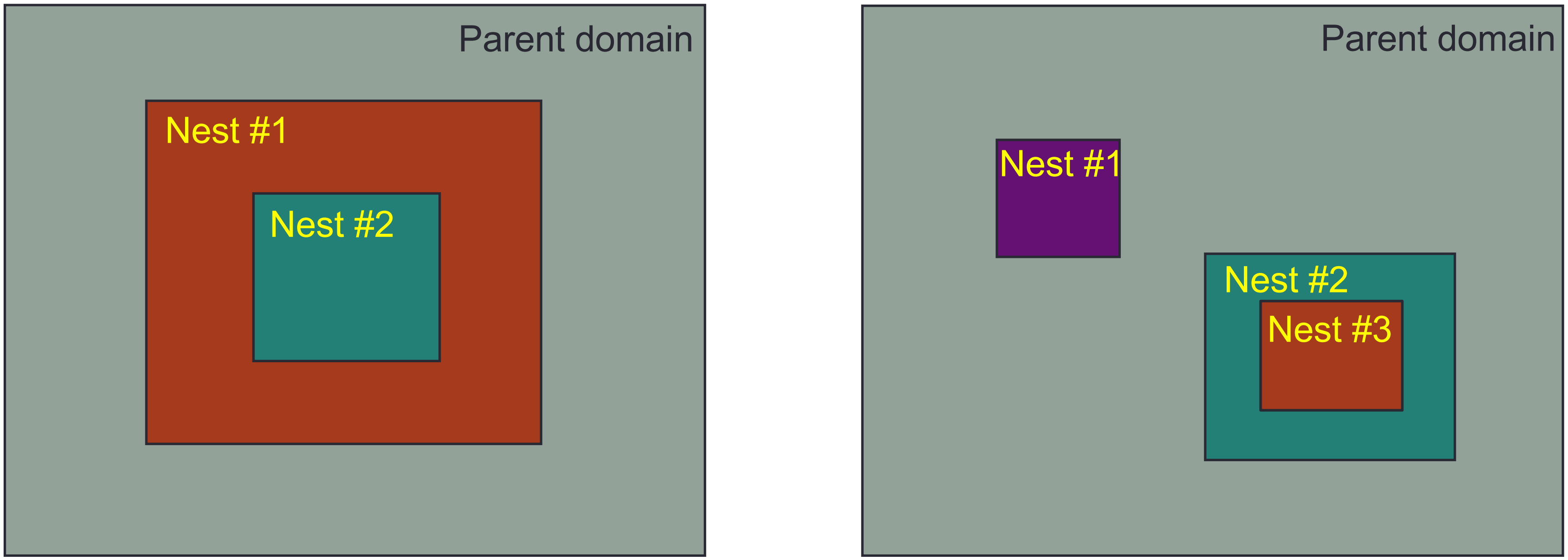


Masked Feedback

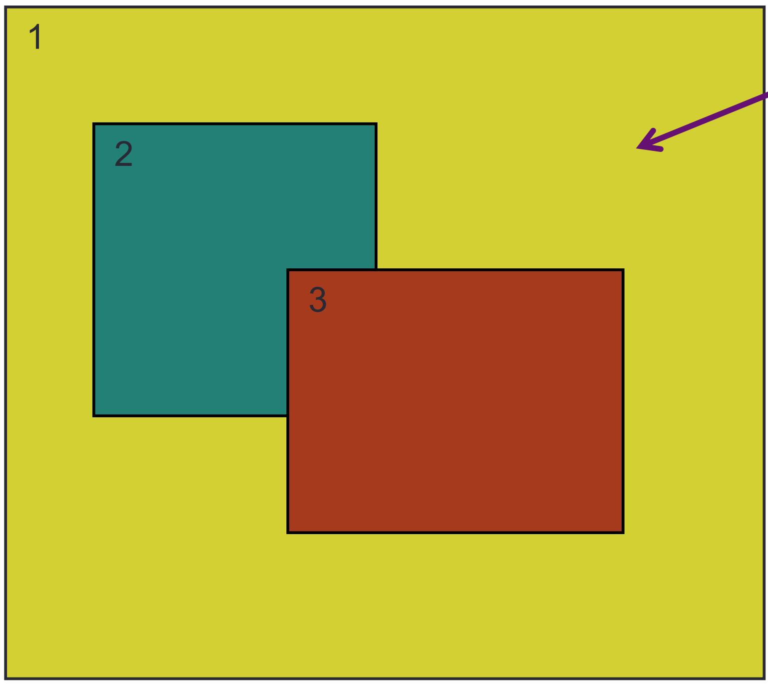


- Single grid value feedback for categorical and masked data

Nests that are OK

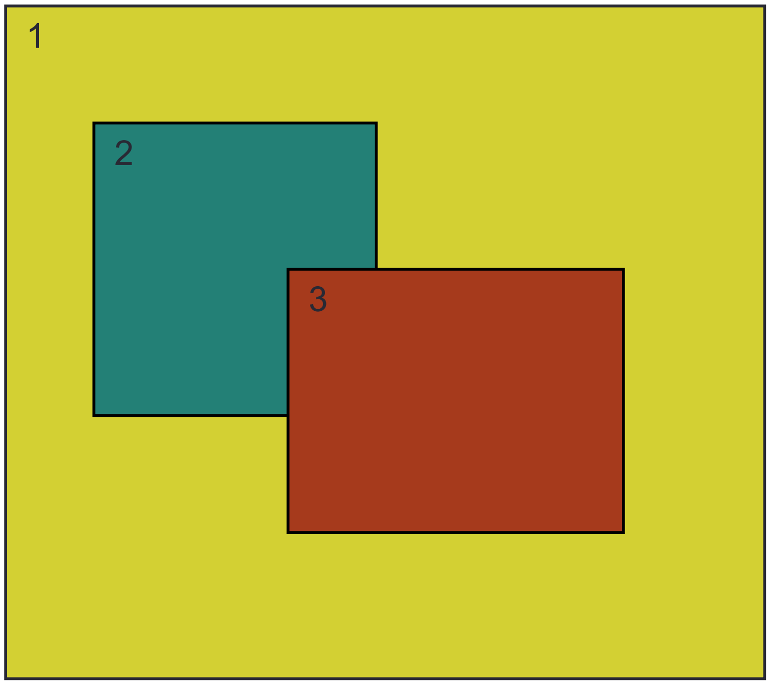


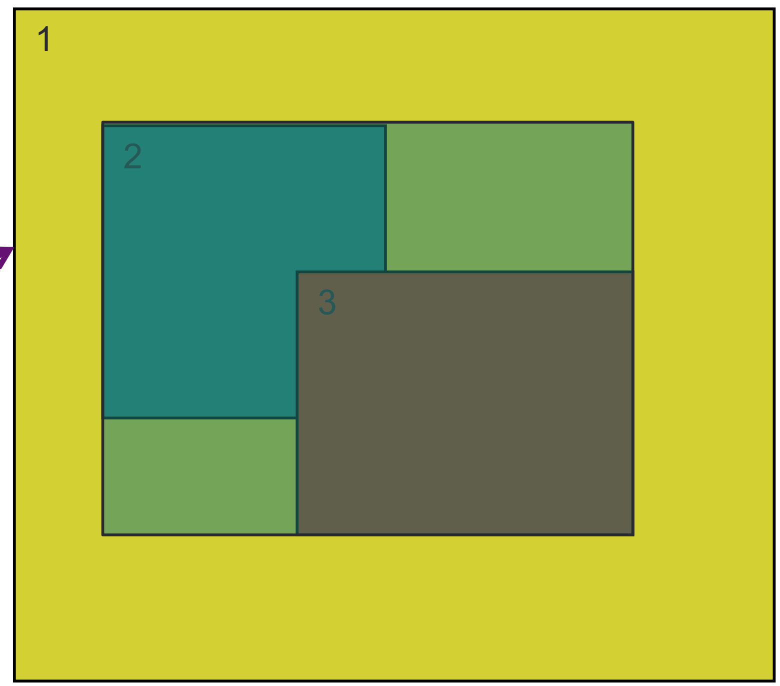
Nests that are NOT OK



Child domains *may not* have overlapping points in the parent domain (possible if Feedback is off).

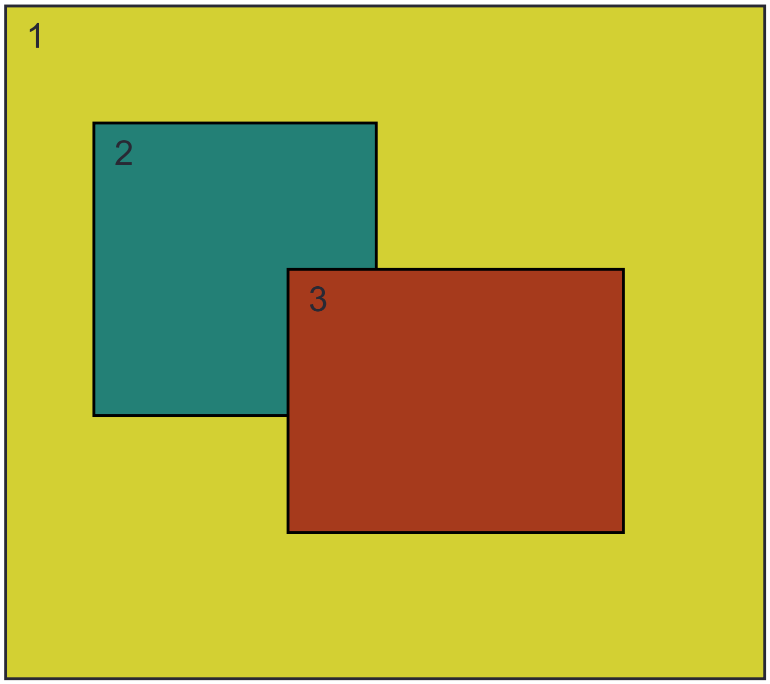
Nests that are NOT OK

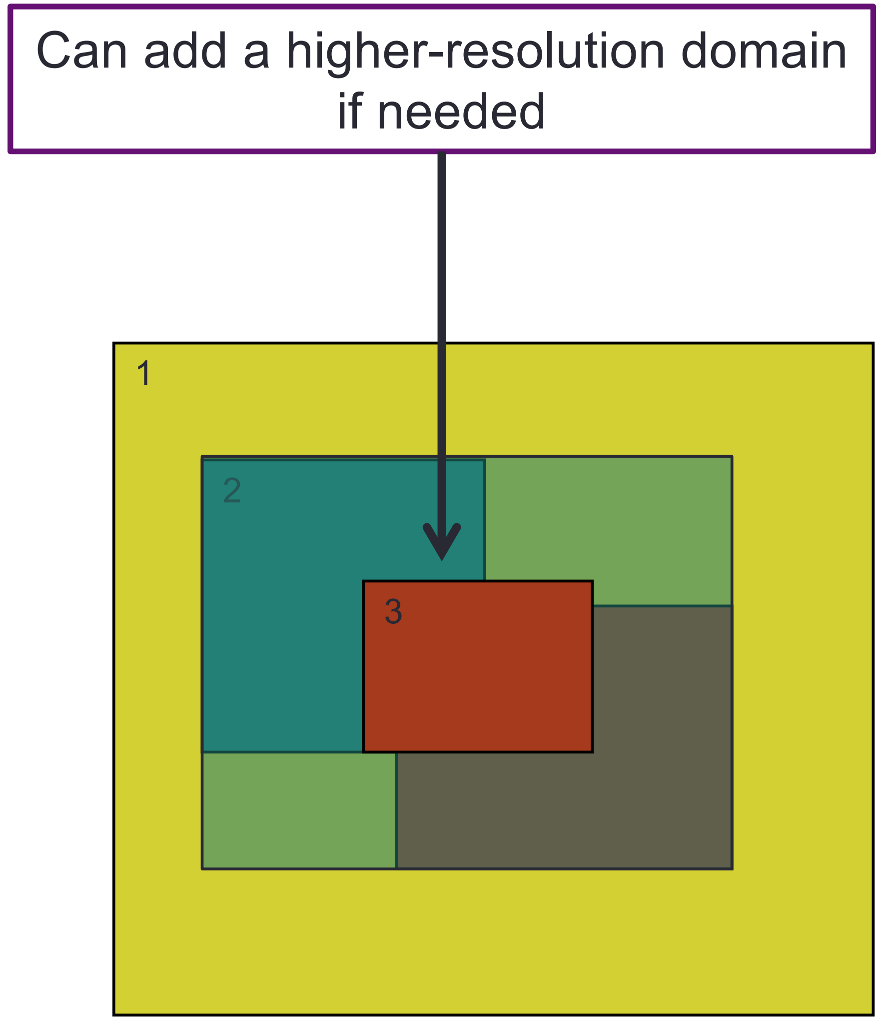




It's best to combine domains to create a single large fine-resolution nested domain

Nests that are NOT OK





Nesting Set-up and Run

Compiling for Nesting (WRF)

```
------------------------------------------------------------------------
Please select from among the following Darwin ARCH options:

  1. (serial)   2. (smpar)   3. (dmpar)   4. (dm+sm)   PGI (pgf90/pgcc)
  5. (serial)   6. (smpar)   7. (dmpar)   8. (dm+sm)   INTEL (ifort/icc)
  9. (serial)  10. (smpar)  11. (dmpar)  12. (dm+sm)   INTEL (ifort/clang)
 13. (serial)               14. (dmpar)                GNU (g95/gcc)
 15. (serial)  16. (smpar)  17. (dmpar)  18. (dm+sm)   GNU (gfortran/gcc)
 19. (serial)  20. (smpar)  21. (dmpar)  22. (dm+sm)   GNU (gfortran/clang)
 23. (serial)               24. (dmpar)                IBM (xlf90_r/cc)
 25. (serial)  26. (smpar)  27. (dmpar)  28. (dm+sm)   PGI (pgf90/pgcc): -f90=pgf90

Enter selection [1-28] : 9
------------------------------------------------------------------------
Compile for nesting? (0=no nesting, 1=basic, 2=preset moves, 3=vortex following) [default 0]:
```

Compile with nesting option (1=basic)

*Note: Unless compiling for a moving nest, or 2D idealized case, there's no reason to not always choose "basic." It takes no longer to build.

namelist.wps - WPS

namelist.wps set-up: &share

To edit the namelist.wps file, make sure you are in the WPS/ directory

```
&share
  wrf_core = 'ARW',
  max_dom = 2,
  start_date = '2012-01-27_00:00:00',' 2012-01-27_00:00:00'
  end_date = '2012-01-28_00:00:00',' 2012-01-27_00:00:00'
  interval_seconds = 21600
  io_form_geogrid = 2,
/
```

real.exe only requires initial time for fine domain (unless doing nudging or SST-update in the nest)

Make sure to edit start/end dates for all domains!

namelist.wps set-up: &geogrid

```
&geogrid

   parent_id         =   1,      1,
   parent_grid_ratio =   1,      3,
   i_parent_start    =   1,     70,
   j_parent_start    =   1,     67,

   e_we              =  175,   181,
   e_sn              =  145,   181,
   geog_data_res     =  'default', 'default',


   dx                = 30000,
   dy                = 30000,
   map_proj      = 'lambert',
   ref_lat       = 37.0,
   ref_lon       = -97.0,
   truelat1      = 45.0,
   truelat2      = 30.0,
   stand_lon     = -97.0,
   geog_data_path = '/data/static/geog/'
/
```

Used for nesting purposes

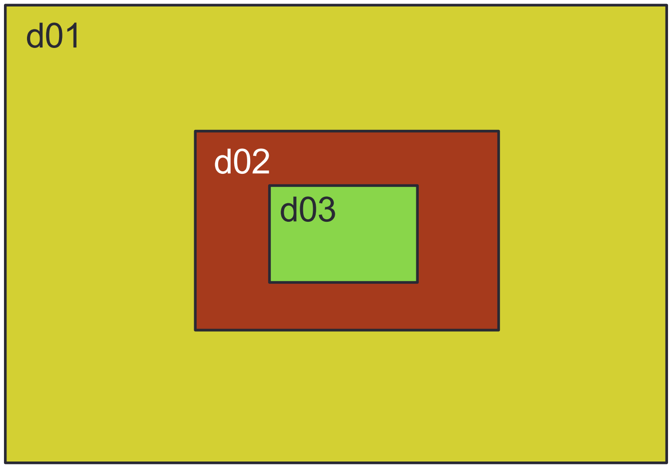
- **parent_grid_ratio**: what is the grid ratio for each nest? (must be integer)
- **i/j_parent_start:** where is it located inside its parent?

Domain sizes: How many grid points does each domain have?

namelist.wps set-up: &geogrid

```
&geogrid

   parent_id         =   1,        1,
   parent_grid_ratio =   1,        3,
   i_parent_start    =   1,       70,
   j_parent_start    =   1,       67,

   e_we              = 175,      181,
   e_sn              = 145,      181,
   geog_data_res     = 'default', 'default',


   dx                = 30000,
   dy                = 30000,
   map_proj      = 'lambert',
   ref_lat       = 37.0,
   ref_lon       = -97.0,
   truelat1      = 45.0,
   truelat2      = 30.0,
   stand_lon     = -97.0,
   geog_data_path = '/data/static/geog/'
/
```

parent_id:
The domain # of the nest's parent

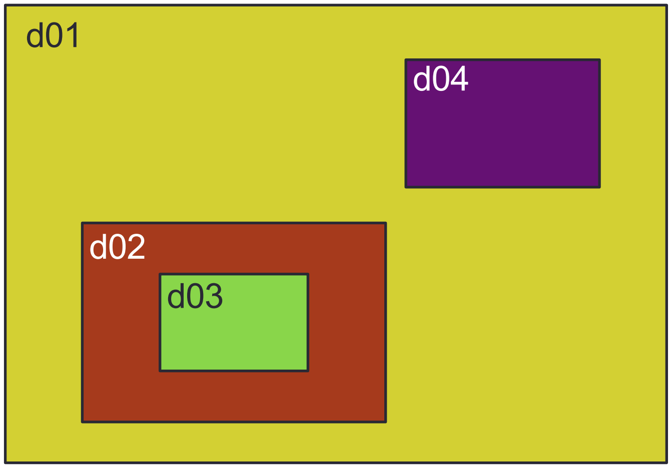


parent_id = 1, 1, 2

namelist.wps set-up: &geogrid

```
&geogrid

   parent_id          =   1,        1,
   parent_grid_ratio  =   1,        3,
   i_parent_start     =   1,       70,
   j_parent_start     =   1,       67,

   e_we               =  175,     181,
   e_sn               =  145,     181,
   geog_data_res      =  'default', 'default',


   dx                 = 30000,
   dy                 = 30000,
   map_proj      = 'lambert',
   ref_lat       = 37.0,
   ref_lon       = -97.0,
   truelat1      = 45.0,
   truelat2      = 30.0,
   stand_lon     = -97.0,
   geog_data_path = '/data/static/geog/'
/
```

parent_id:
The domain # of the nest's parent



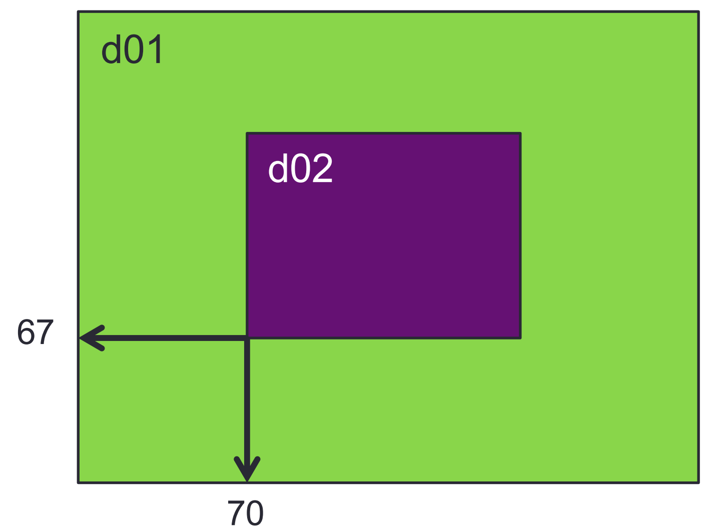
parent_id = 1, 1, 2, 1

namelist.wps set-up: &geogrid

```
&geogrid

  parent_id          =  1,        1,
  parent_grid_ratio  =  1,        3,
  i_parent_start     =  1,       70,
  j_parent_start     =  1,       67,

  e_we               =  175,    181,
  e_sn               =  145,    181,
  geog_data_res      =  'default', 'default',


  dx                 = 30000,
  dy                 = 30000,
  map_proj      = 'lambert',
  ref_lat       = 37.0,
  ref_lon       = -97.0,
  truelat1      = 45.0,
  truelat2      = 30.0,
  stand_lon     = -97.0,
  geog_data_path = '/data/static/geog/'
/
```

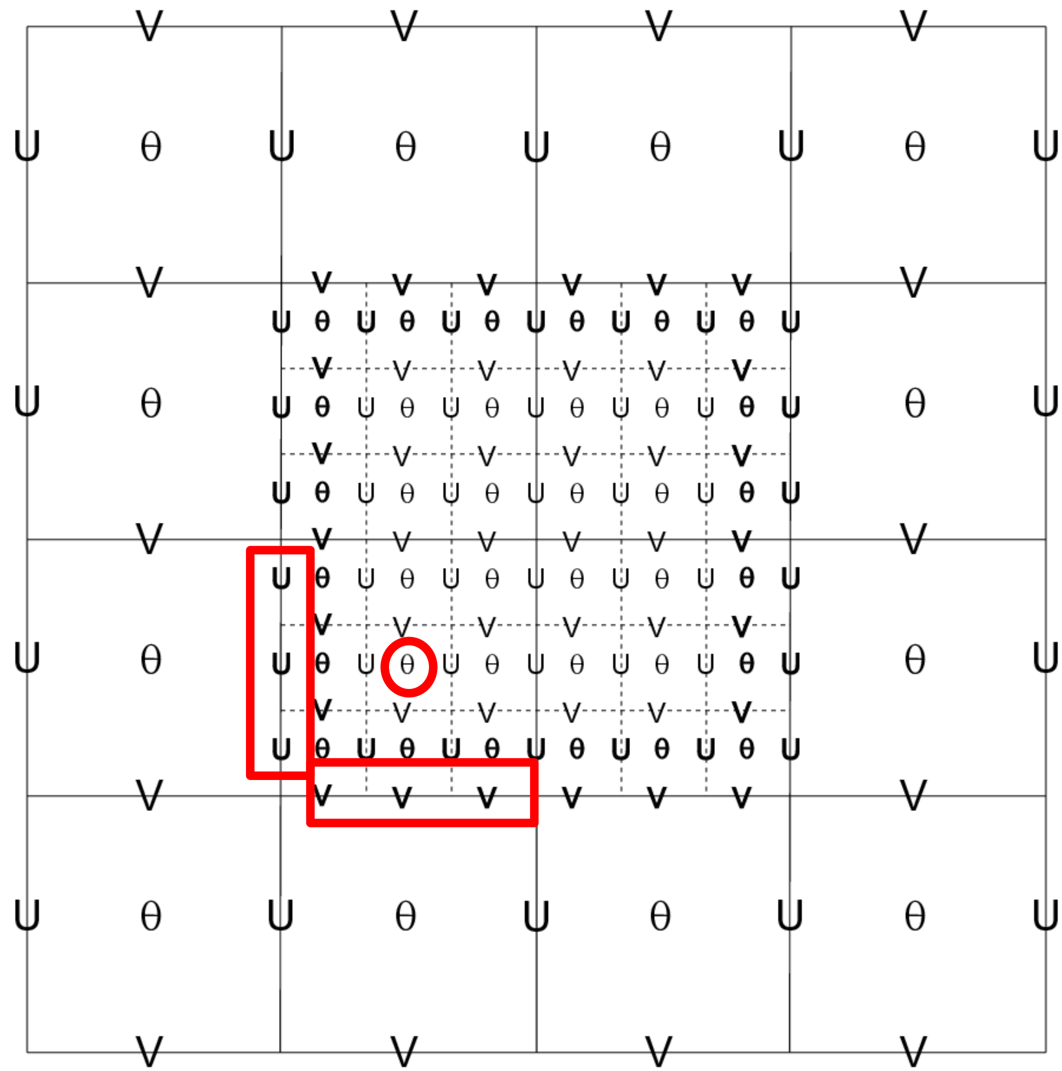
parent_grid_ratio:
recommended ratios are 3:1 or 5:1
(odd ratios, less than 7)

i/j_parent_start:



Feedback 3:1 Ratio

When using feedback, conditions are fed back to the parent domain from the child along the rows and columns, and at the mass points (center)



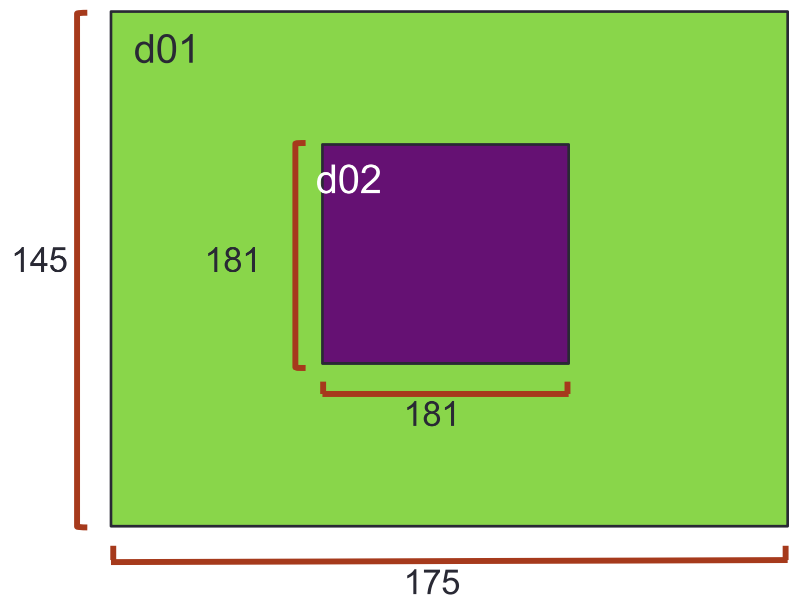
U: east-west velocities
V: south-north velocities
Θ: all other meteorological data

Averaging is performed

namelist.wps set-up: &geogrid

```
&geogrid

 parent_id          =   1,        1,
 parent_grid_ratio  =   1,        3,
 i_parent_start     =   1,       70,
 j_parent_start     =   1,       67,

 e_we               =  175,     181,
 e_sn               =  145,     181,
 geog_data_res      =  'default', 'default',


 dx                 = 30000,
 dy                 = 30000,
 map_proj       = 'lambert',
 ref_lat        = 37.0,
 ref_lon        = -97.0,
 truelat1       = 45.0,
 truelat2       = 30.0,
 stand_lon      = -97.0,
 geog_data_path = '/data/static/geog/'
/
```

e_we and e_sn:
Each domain's full west-east and south-north dimensions



Notes:

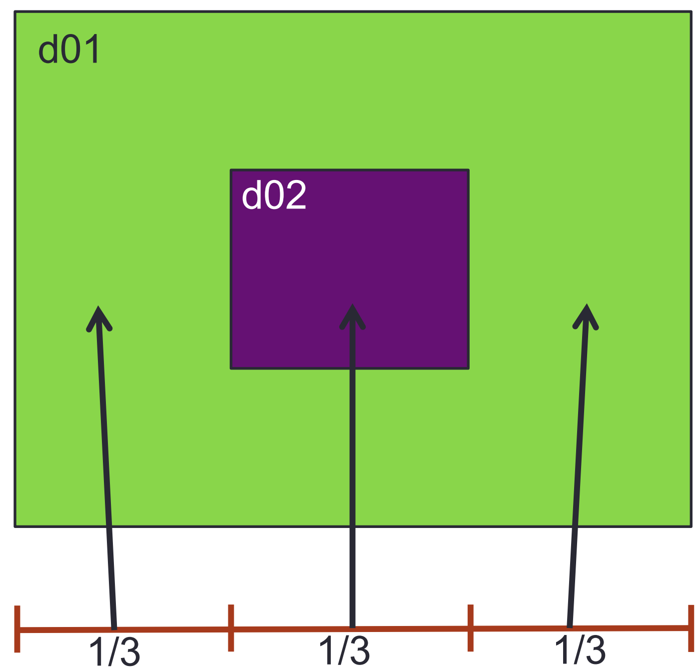
- Domains should be no smaller than about 100x100
- Avoid placing any boundaries over complex terrain
- Keep nest away from coarse domain

namelist.wps set-up: &geogrid

```
&geogrid

 parent_id          =   1,       1,
 parent_grid_ratio  =   1,       3,
 i_parent_start     =   1,      70,
 j_parent_start     =   1,      67,

 e_we               = 175,     181,
 e_sn               = 145,     181,
 geog_data_res      = 'default', 'default',


 dx                 = 30000,
 dy                 = 30000,
 map_proj      = 'lambert',
 ref_lat       = 37.0,
 ref_lon       = -97.0,
 truelat1      = 45.0,
 truelat2      = 30.0,
 stand_lon     = -97.0,
 geog_data_path = '/data/static/geog/'
/
```

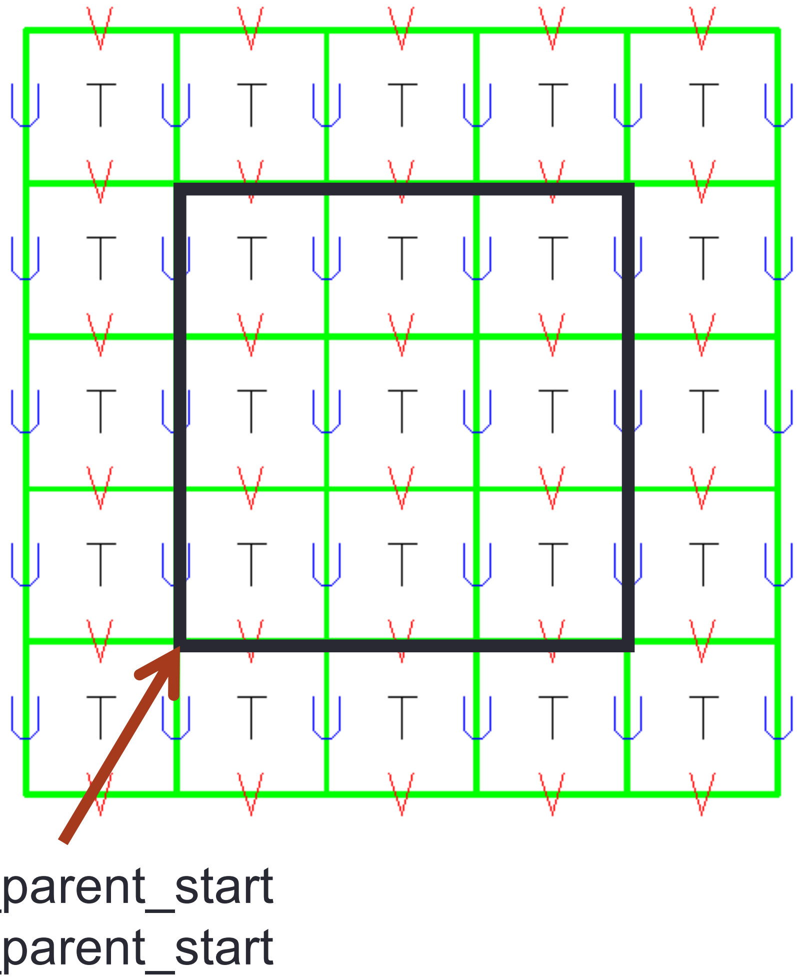
Minimum distance between nest boundary and parent boundary:

- 4 grid cells
- need MUCH larger buffer zone



- Good practice to have ~1/3 of coarse-grid surrounding each side of nest
- Nest can be placed a bit downstream of the inflow boundary

WRF Parent-nest Domain Overlap



- The nested domain can be placed *anywhere* within the parent domain and the nested grid cells will exactly overlap the parent cells at the coincident cell boundaries

- Coincident parent/nest grid points:
  - eliminate the need for complex, generalized remapping calculations
  - enhances model performance and portability.

namelist.wps set-up: &geogrid

```
&geogrid

parent_id          =   1,        1,
parent_grid_ratio  =   1,        3,
i_parent_start     =   1,       70,
j_parent_start     =   1,       67,

e_we               =  175,     181,
e_sn               =  145,     181,
geog_data_res      =  'default', 'default',


dx                 = 30000,
dy                 = 30000,
map_proj      = 'lambert',
ref_lat       = 37.0,
ref_lon       = -97.0,
truelat1      = 45.0,
truelat2      = 30.0,
stand_lon     = -97.0,
geog_data_path = '/data/static/geog/'
/
```

dx and dy:
Only need the coarse domain resolution. The geogrid program calculates the nest resolution(s) using the "parent_grid_ratio"

***Note:**
No changes need to be made to the &ungrib and &metgrid namelists records for nesting purposes

namelist.input (WRF)

namelist.input set-up: &time_control

```
&time_control
 run_days                  = 0,
 run_hours                 = 24,
 run_minutes               = 0,
 run_seconds               = 0,
 start_year                = 2012, 2012,  2012,
 start_month               = 01,   01,    01,
 start_day                 = 27,   27,    27,
 start_hour                = 00,   00,    00,
 end_year                  = 2012, 2012,  2012,
 end_month                 = 01,   01,    01,
 end_day                   = 28,   28,    28,
 end_hour                  = 00,   00,    00,
 interval_seconds          = 10800
 input_from_file           = .true., .true., .true.,
 history_interval          = 360,  60,    60
 frames_per_outfile        = 1000, 1,     1
 restart                   = .false.
 restart_interval          = 180
 io_form_history           = 2
 io_form_restart           = 2
/
```

** To edit the namelist.input file, make sure you are in the *WRF/test/em_real/* (or *WRF/run/*) directory

start/end date/times:
These values *typically* will be the same for all domains

history_interval:
How often history is written out.
*May choose to have more frequent output time for nests

frames_per_outfile:
The number of history intervals in a single file.

Time and Frequency Clarification

```
&time_control
 interval_seconds        = 10800
 history_interval        =  60,     60,       60
 frames_per_outfile      = 1,       1,        1
/

&domains
 time_step               = 180
/
```

interval_seconds:
The number of seconds between each data input file (met_em*)

time_step:
How often the model integrates forward (in seconds). 180 = every 3 mins of simulation time

history_interval:
Frequency (in simulation minutes) that data is written/recorded.
= 60: history is recorded every 1 hour
Since time_step=180, each history recording includes 20 time steps of integration.

frames_per_outfile:
The number of history intervals in a single file.
In our example above, if it's set to 1, you should get a wrfout file for each simulation hour. If we set it to 3, you would have 3 history times (or 3 hours) in a single wrfout* file. If we set to something large, like 1000, you could store up to 1000 history times in a single wrfout* file.

namelist.input set-up: &domains

```
&domains
 time_step                      = 180,
 time_step_fract_num            = 0,
 time_step_fract_den            = 1,
 max_dom                        = 2,
 e_we                           = 175,   181,   94,
 e_sn                           = 145,   181,   91,
 e_vert                         = 40,    40,    40,
 p_top_requested                = 5000,
 num_metgrid_levels             = 32,
 num_metgrid_soil_levels        = 4,
 dx                             = 30000, 10000, 3333.33,
 dy                             = 30000, 10000, 3333.33,
 grid_id                        = 1,     2,     3,
 parent_id                      = 1,     1,     2,
 i_parent_start                 = 1,     70,    30,
 j_parent_start                 = 1,     67,    30,
 parent_grid_ratio              = 1,     3,     3,
 parent_time_step_ratio         = 1,     3,     3,
 feedback                       = 1,
/
```

max_dom:
Activate nests - # of domains to run

e_we and e_sn:
should match namelist.wps values

e_vert:
All columns usually have the same value

dx/dy:
must set values for each domain.
make sure values correspond with "parent_grid_ratio"
- for non-integer grid resolutions, use at least two decimal places

namelist.input set-up: &domains

```
&domains
 ...........
 grid_id                  = 1,   2,   3,
 parent_id                = 1,   1,   2,
 i_parent_start           = 1,   70,  30,
 j_parent_start           = 1,   67,  30,
 parent_grid_ratio        = 1,   3,   3,
 parent_time_step_ratio   = 1,   3,   3,
 feedback                 = 1,
/
```

All must be set to the same values used in namelist.wps

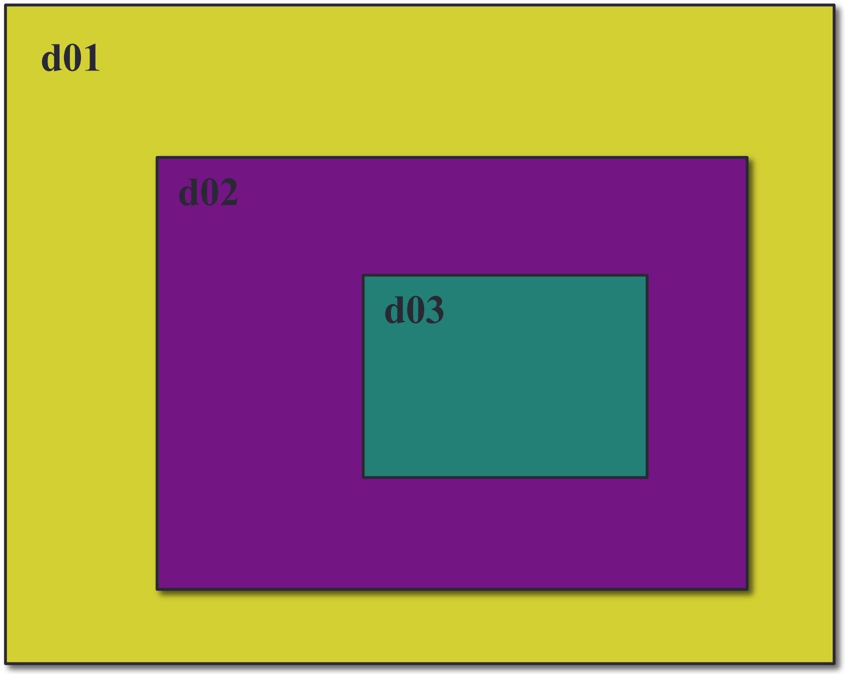
feedback:
Whether a nest will overwrite parent results
- 2-way nesting: feedback = 1
- 1-way nesting: feedback = 0

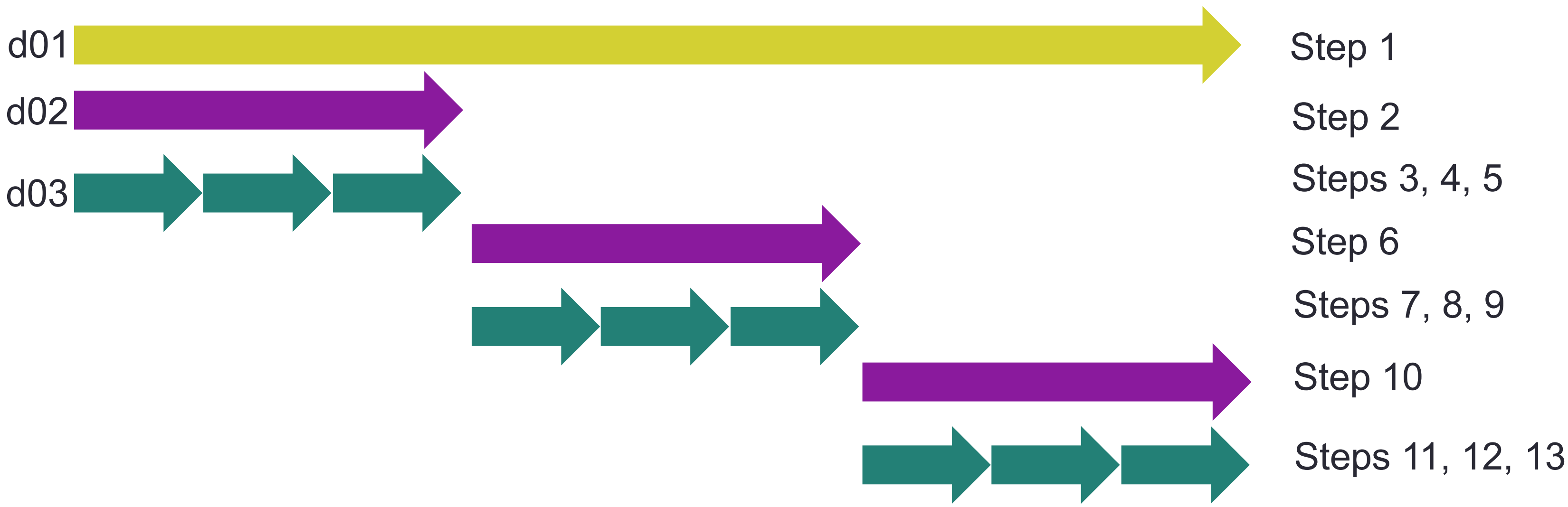
parent_time_step_ratio:
See next slide!

Nested 3:1 Parent Time Step Ratio

- Example: 3-domain nested run
- time_step = 180

  parent_time_step_ratio = 1, 3, 3,
  - D01: a single 3 min dt
  - D02: a single 1 min dt
  - D03: 20 second intervals, up to 1 min





namelist.input set-up: &physics

- Use the same physics options for all domains for all schemes
  - **Exceptions**:
    - cumulus_scheme (cu_physics): may need to be turned off for a nest that has a grid distance of only a few kilometers
    - may turn off PBL scheme for resolutions close to 100 m

- Each domain should use the same value for physics calling frequency parameters (based on DX for d01)
  - radt: radiation time step
  - bldt: boundary layer time step
  - cudt: cumulus scheme time step

Computationally inexpensive – no reason to not always set to zero (run every time step)

Where do I start?

- Namelist templates provided in test/em_real

- Helpful documentation:
  - **README.namelist** (in test/em_real/)
  - **examples.namelist** (in test/em_real/)
  - **Users' Guide, Chapter 5**
    - http://www2.mmm.ucar.edu/wrf/users/docs/user_guide_v4/V4.1/users_guide_chap5.htm
  - **Namelist Best Practice web pages:**
    - WPS: http://www2.mmm.ucar.edu/wrf/users/namelist_best_prac_wps.html
    - WRF: http://www2.mmm.ucar.edu/wrf/users/namelist_best_prac_wrf.html

- Not all namelist options are domain dependent. If in doubt:
  - **Registry.EM_COMMON** or **registry.io_boilerplate** (found in WRF/Registry/)

    * grep for parameter names – look for "max_dom" (max_dom means expected value for each domain
  - Rule of thumb: If default namelist only has 1 column, don't add values for other columns!

Running Nested WPS

- Modify namelist.wps for multiple domains (additional columns)

- Use same executables for running with a single domain
  - geogrid.exe output: **`geo_em.d01.nc, geo_em.d02.nc`**, etc.
  - ungrib.exe output: same as single domain – not domain dependent
  - metgrid.exe output: **`met_em.d01*, met_em.d02*,`** etc.

Running Nested WRF

- Modify namelist.input for multiple domains (additional columns)

- Link in the met_em* files & issue same executables for running with a single domain

real.exe output:

wrfbdy_d01

- Lateral boundary data for all times (domain 01 only)

wrfinput_d01, wrfinput_d02, etc.

- Single time-level data at the model's start time (for each domain)
- 1 file per domain

wrf.exe output:

wrfout_d01*, wrfout_d02*, etc.

- One for each domain, for each history time (depending on 'frames_per_outfile')

wrfrst_d01*, wrfrst_d02*, etc.

- If "restart_interval" is less than or equal to the integration time

Summary

- Decide the best strategy to run your simulation
  - Based on resolution needed to resolve phenomenon, vs. resolution of input data

- If nesting is required, design your nest configuration
  - Design the coarse domain first
  - Determine the beginning and ending indices of the nest on the coarse domain

- Choose the appropriate nesting strategy:
  - one-way, two-way, or one-way via *ndown*

Questions?