Introduction to Nesting

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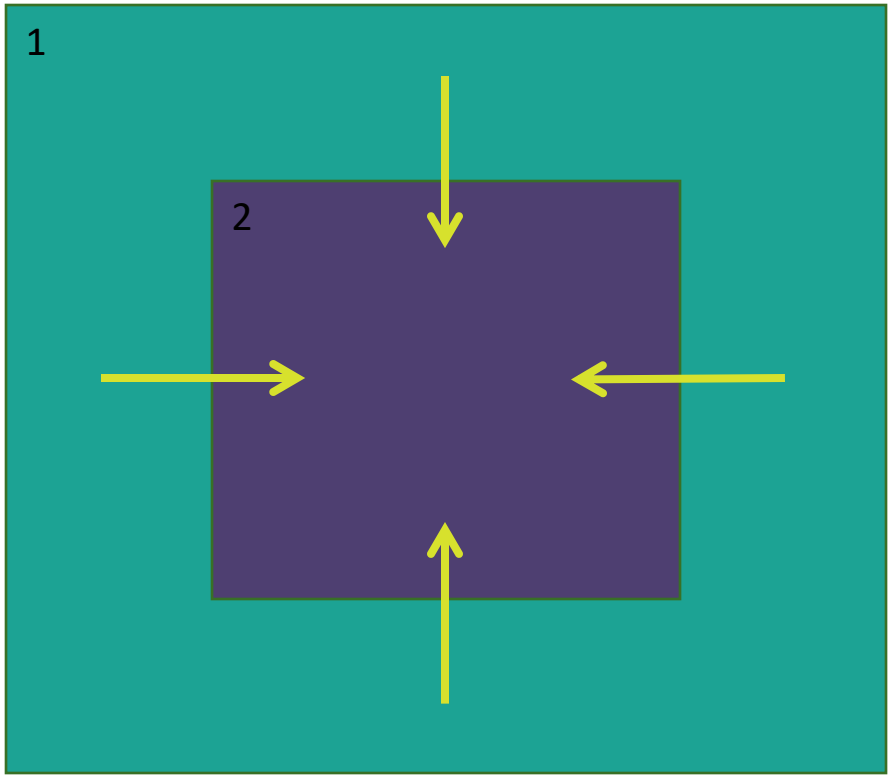
What is a Nest?

- A finer-resolution domain embedded in a coarser-resolution domain, and run together with the coarse domain
- Driven along its lateral boundaries by the parent domain



When should I use a nest?

Do you need to simulate localized phenomena (e.g., convection)?

- What size area do you need to fully include the phenomena?

What resolution is necessary to resolve what you are interested in?

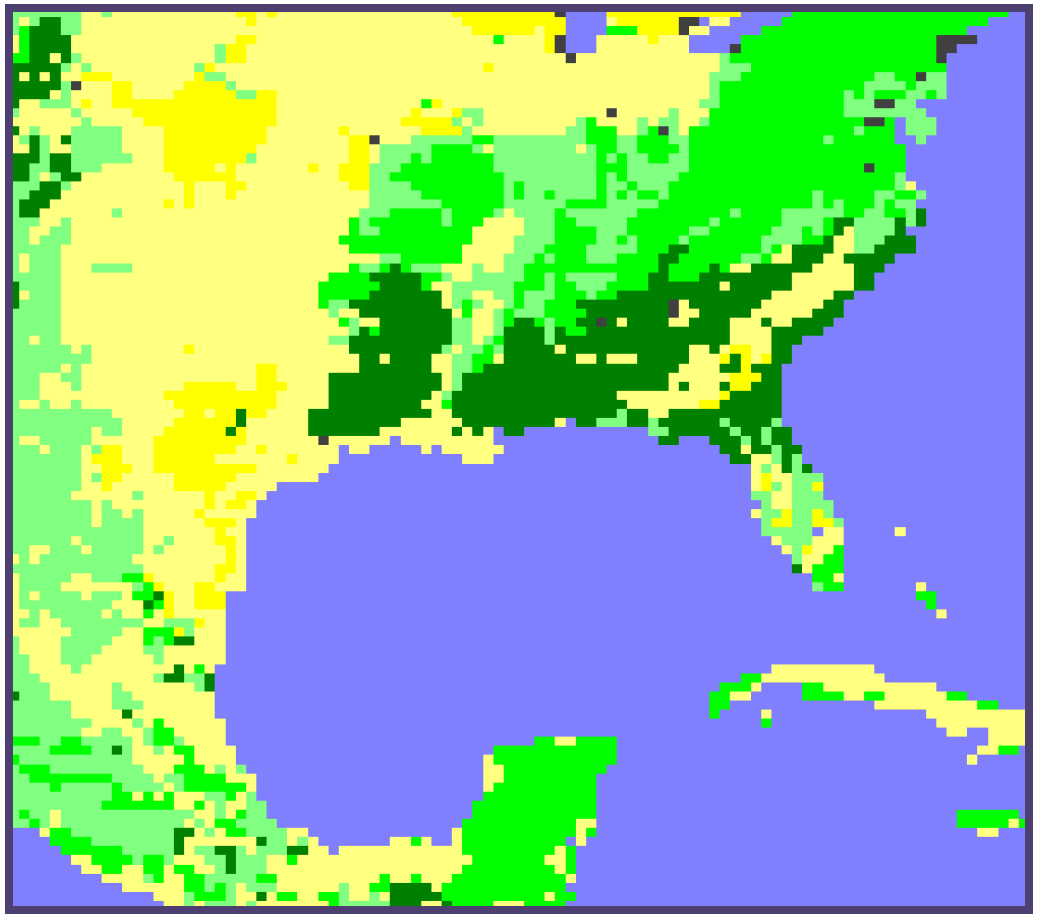
What is the resolution of the input data?

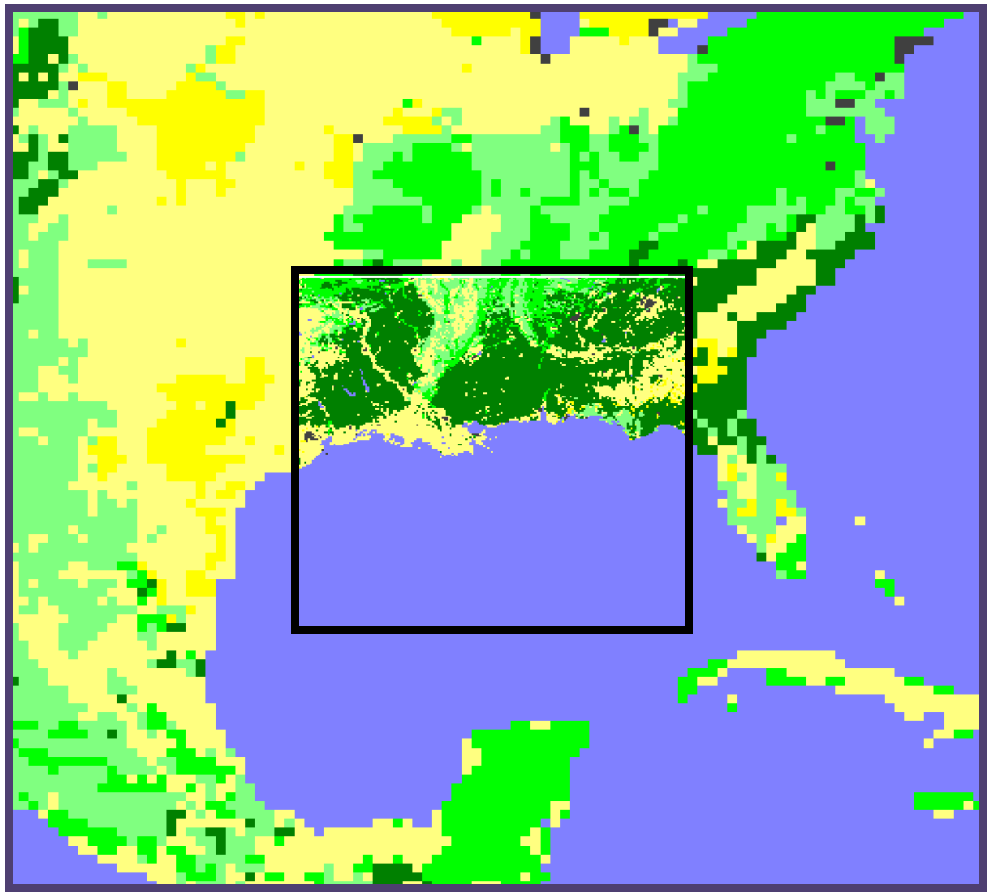
- Input data resolution is too coarse by more than a factor of ~5x the domain resolution

What computing resources are available?

- Computing resources not available for uniform coverage

Coarse vs. Fine Landuse Resolution over Large Domain





Types of Nesting

Standard Nesting

Running all nests simultaneously

- Build WRF with “1-Basic”

Specialized Nesting

Specified move

- Build WRF with “2=preset moves”
- Must specify every move

Automatic move

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

ndown.exe

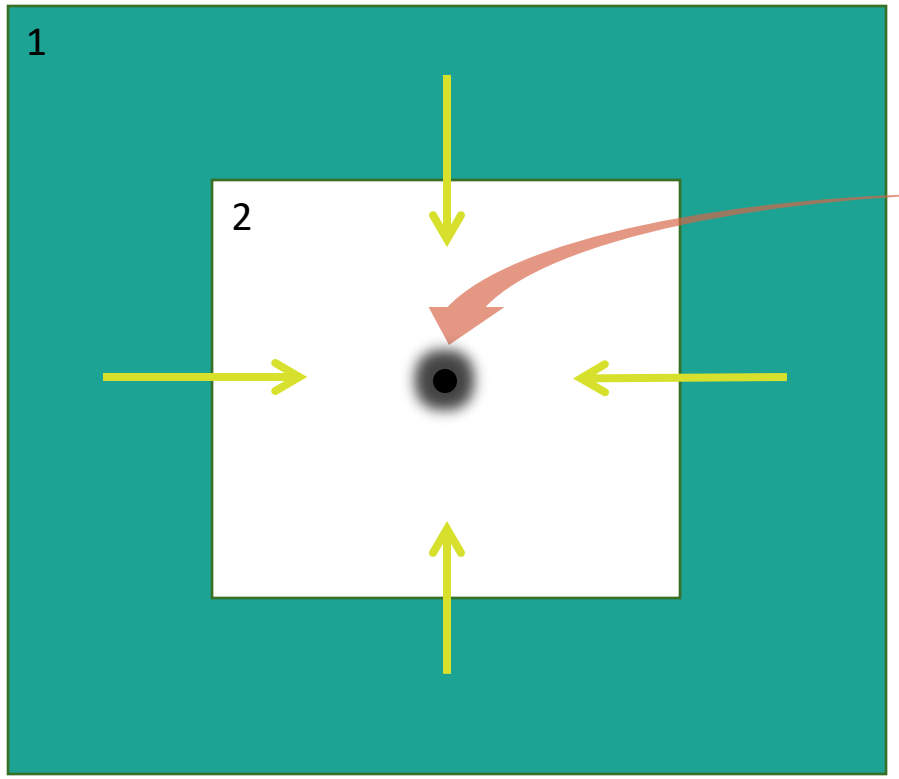
- Use coarser WRF model output to drive finer resolution domains (i.e. ‘downscaling’)
- If you have run a long coarse domain simulation (years) and later decide you want to have a nest with higher resolution.
- If using several nests and domain size for the fine-resolution domain is much different than resolution for coarse domain

Two-way Nesting

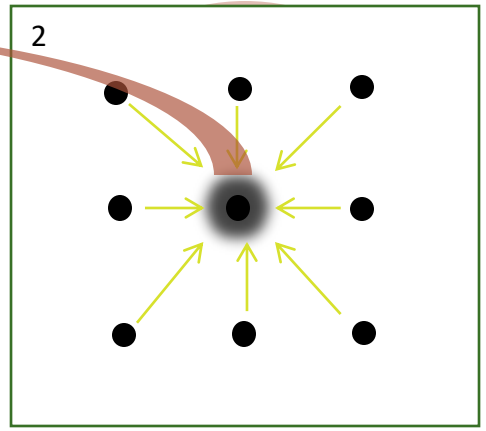
Determined by the namelist parameter “feedback”

feedback = 1 (turned on/two-way)

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



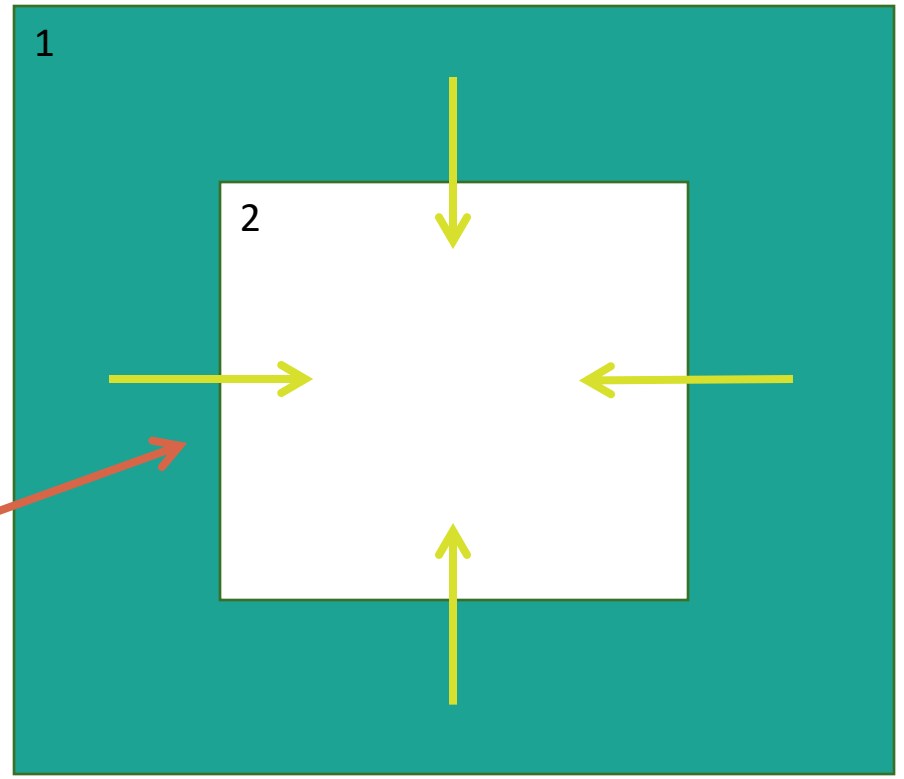
(2) Child values are averaged, and then
sent back to parent to overwrite value
at corresponding grid point



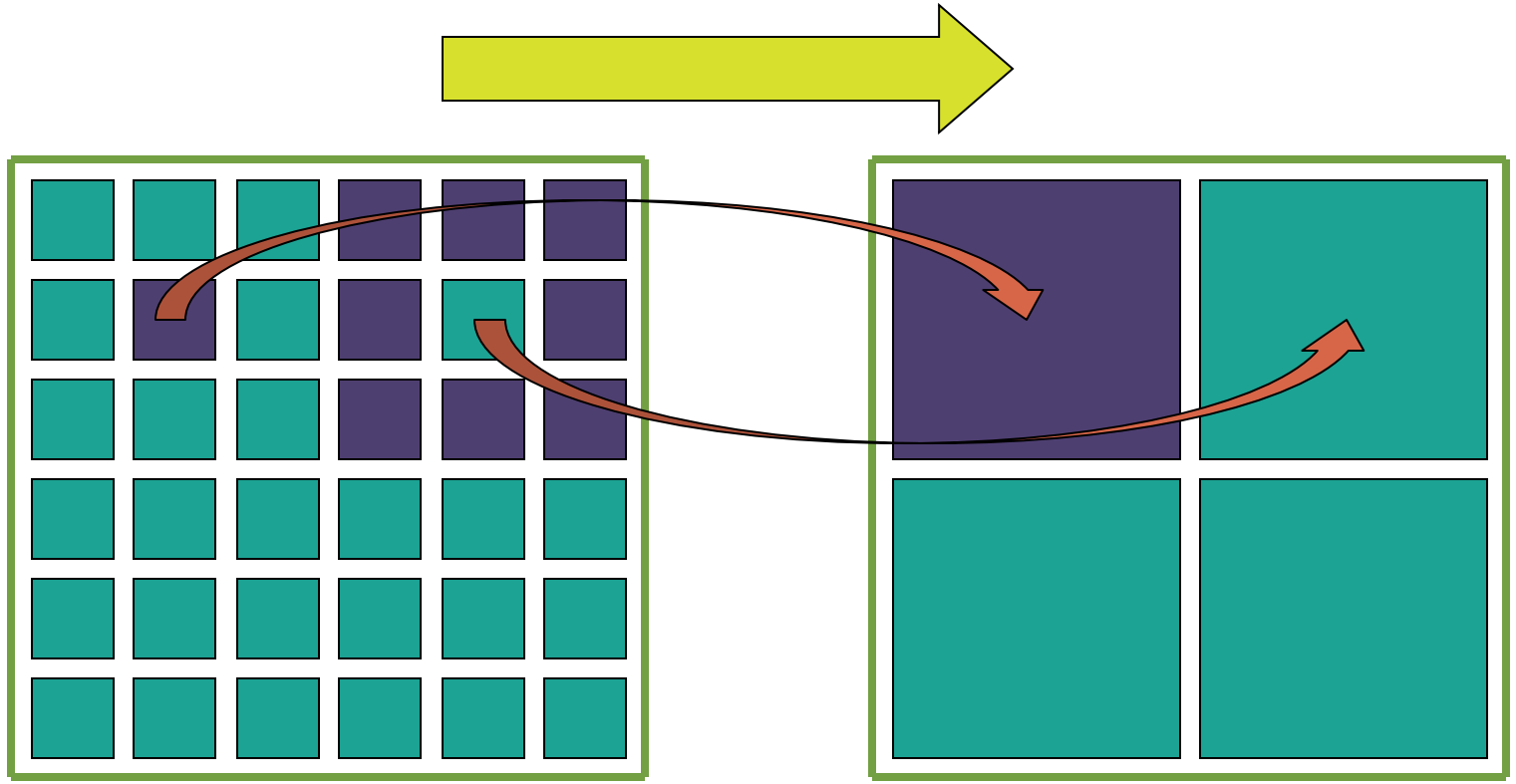
One-way Nesting

feedback = 0 (turned off/one-way)

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

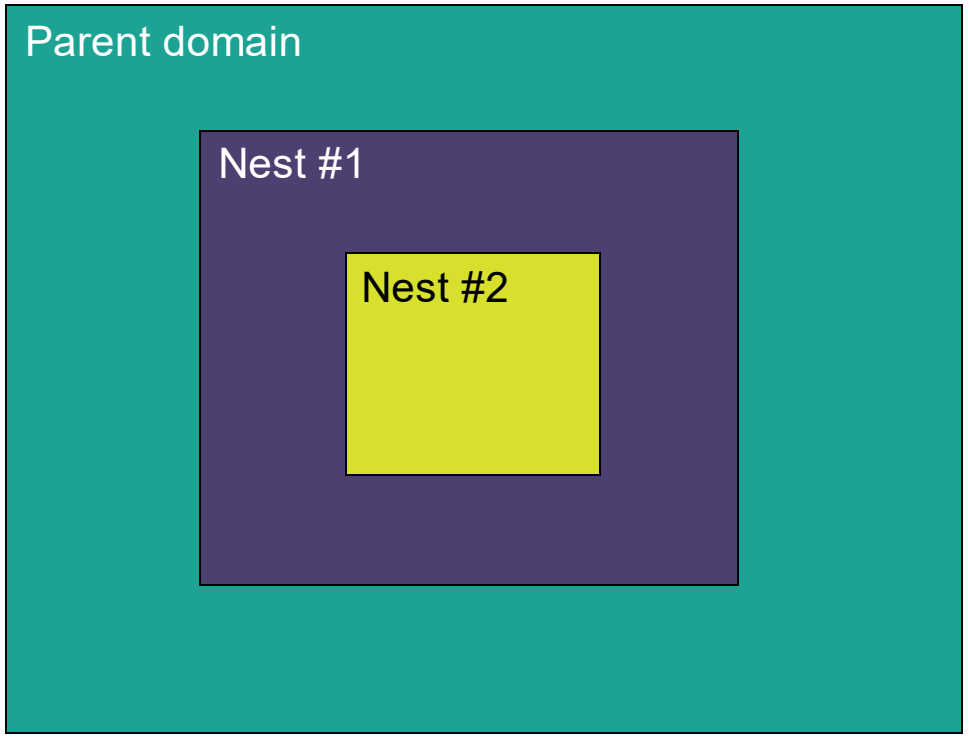


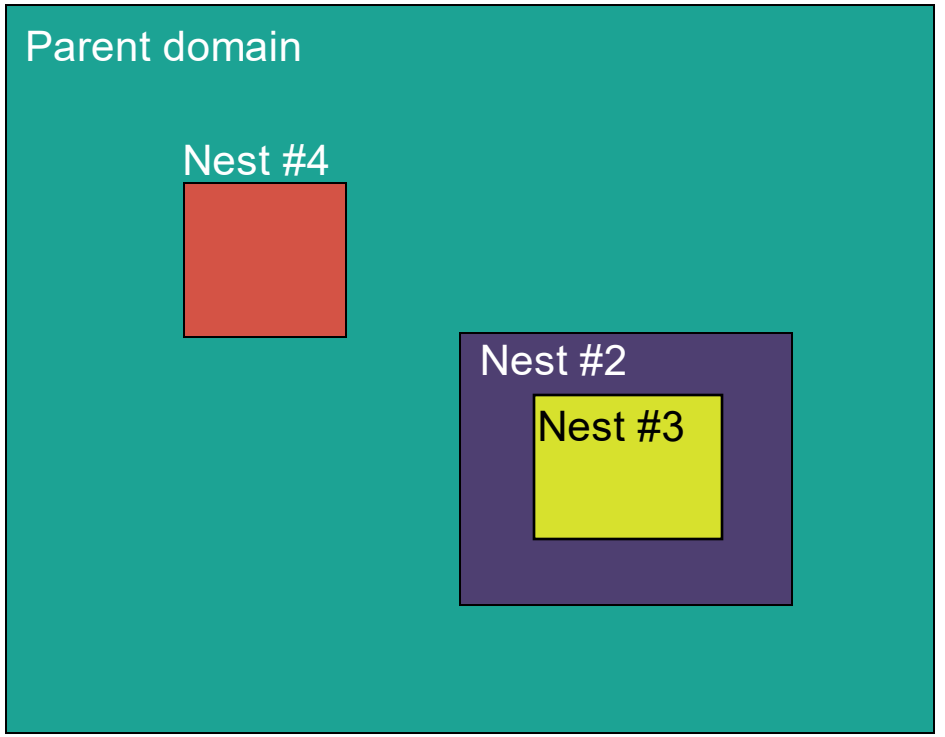
Masked Feedback



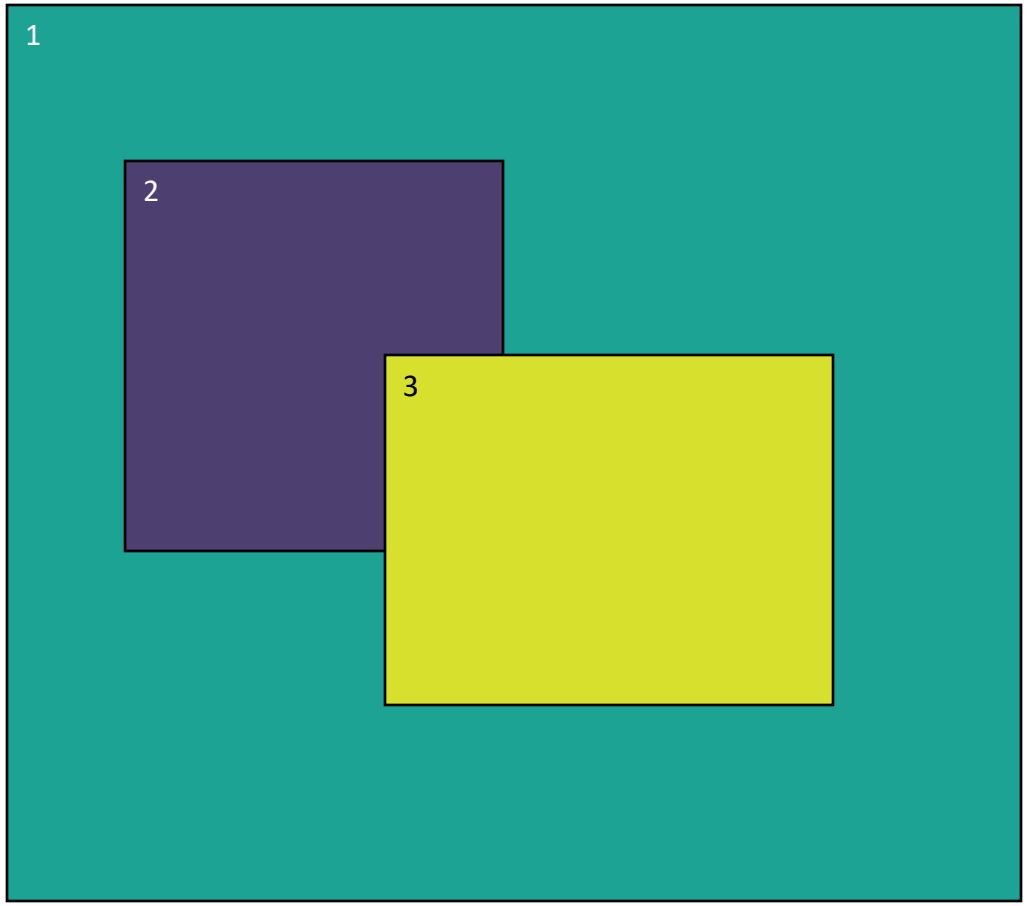
Single grid value feedback for categorical and masked data

Compliant Nest Set-ups



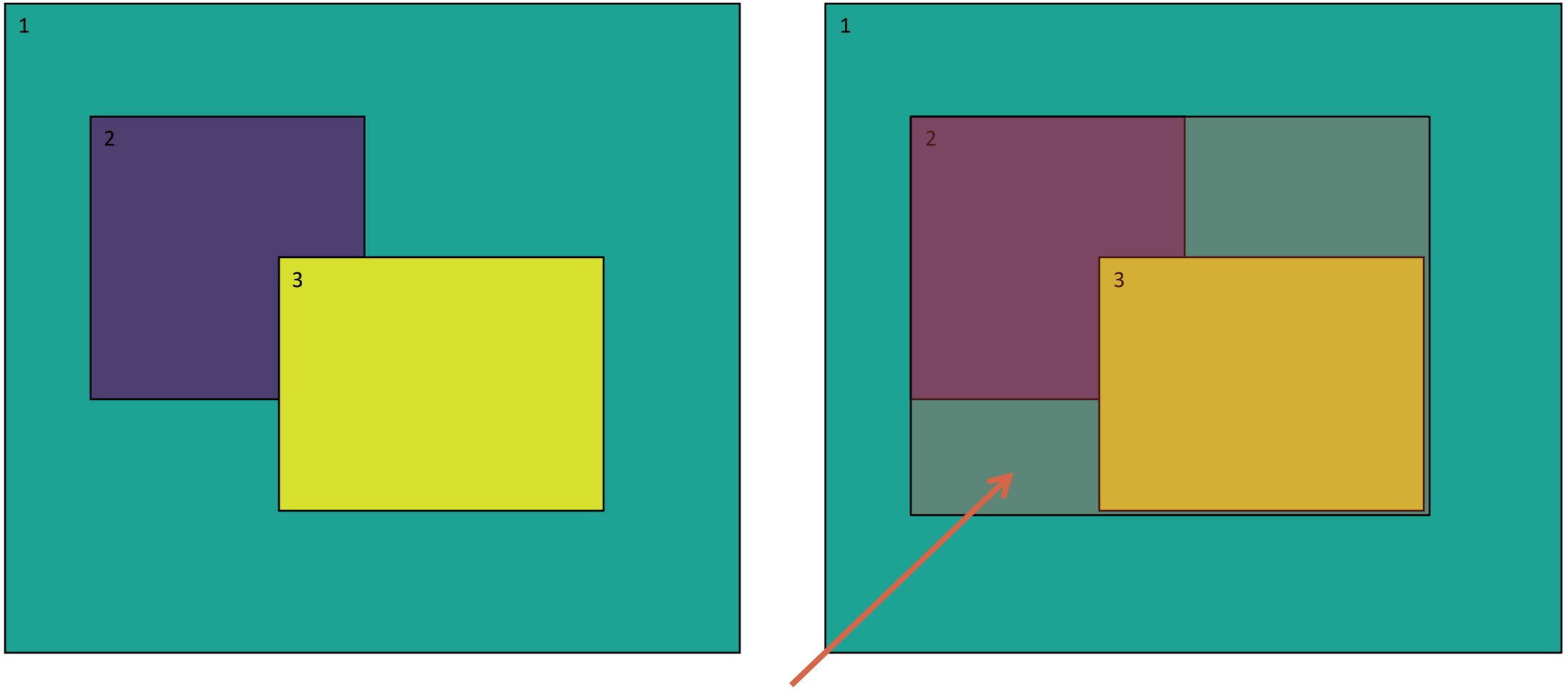


Non-compliant Nest Setups



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

Solution to Nest Overlapping Problem (1)



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

Special Nesting Options

Automatic move

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

```
------------------------------------------------------------------------
Compile for nesting? (1=basic, 2=preset moves, 3=vortex following) [default 1]:
```

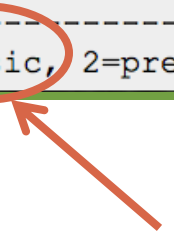
ndown.exe

- 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.
- If using several nests and domain size for the fine-resolution domain is much different than resolution for coarse domain (see this FAQ for additional information: https://forum.mmm.ucar.edu/threads/how-many-processors-should-i-use-to-run-wrf.5082/)

Nesting Set-up and Run

Compiling WRF for Nesting

```
------------------------------------------------------------------------
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.

Nesting Set-up for namelist.wps

```
&share
 wrf_core =          'ARW',
 max_dom =           1,
 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,
/

&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,
 ref_lon   =         -97.00,
 truelat1  =         45.0,
 truelat2  =         30.0,
 stand_lon =         -97.0,
 geog_data_path =    '/data/static/geog'
/

&ungrib
 out_format =        'WPS',
 prefix =            'FILE',
/

&metgrid
 fg_name =           'FILE'
 io_form_metgrid =   2,
/
```

d01

d02

namelist.wps &share for Nesting

```
&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)

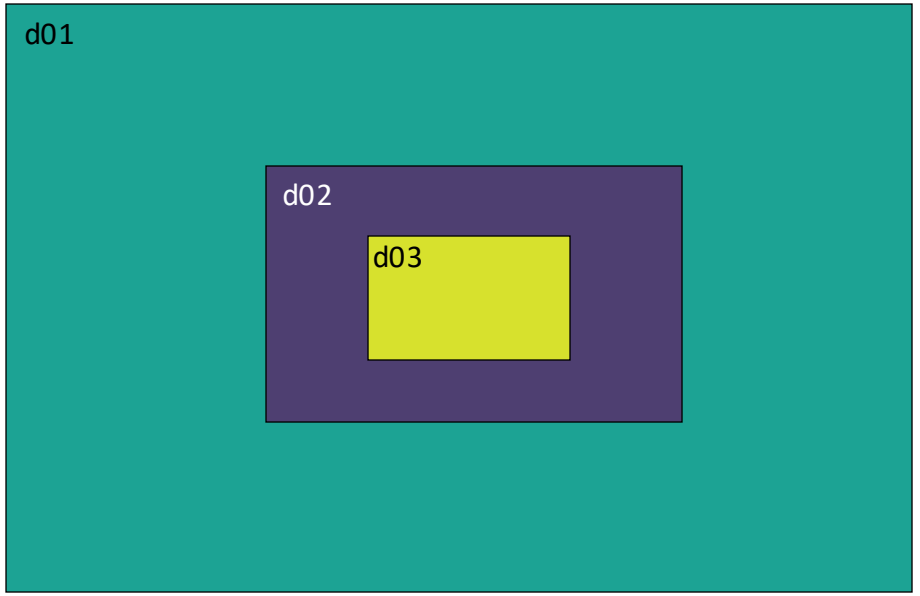
Make sure to edit start/end dates for all domains!

namelist.wps *&geogrid* for Nesting (1)

```
&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



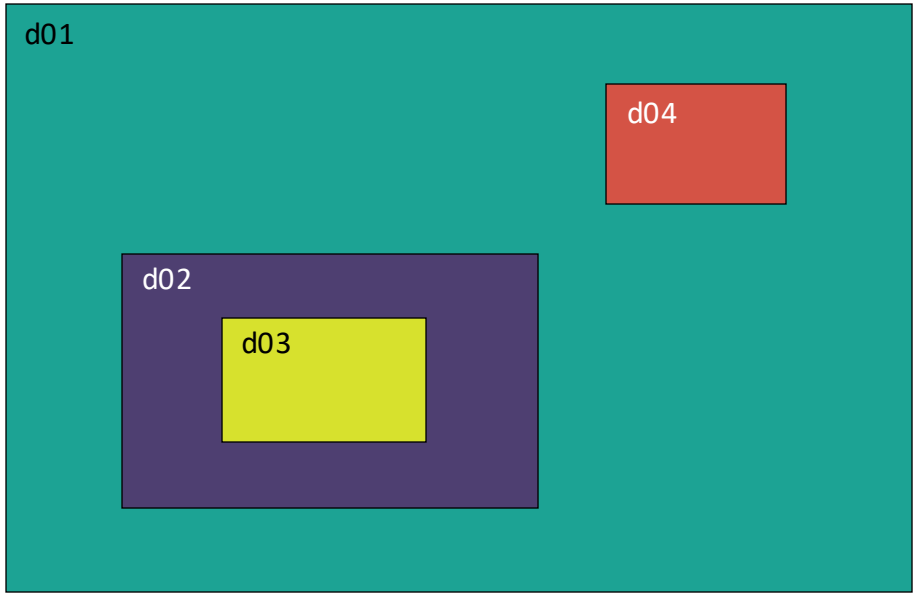
parent_id = 1, 1, 2

namelist.wps *&geogrid* for Nesting (2)

```
&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 *&geogrid* for Nesting (3)

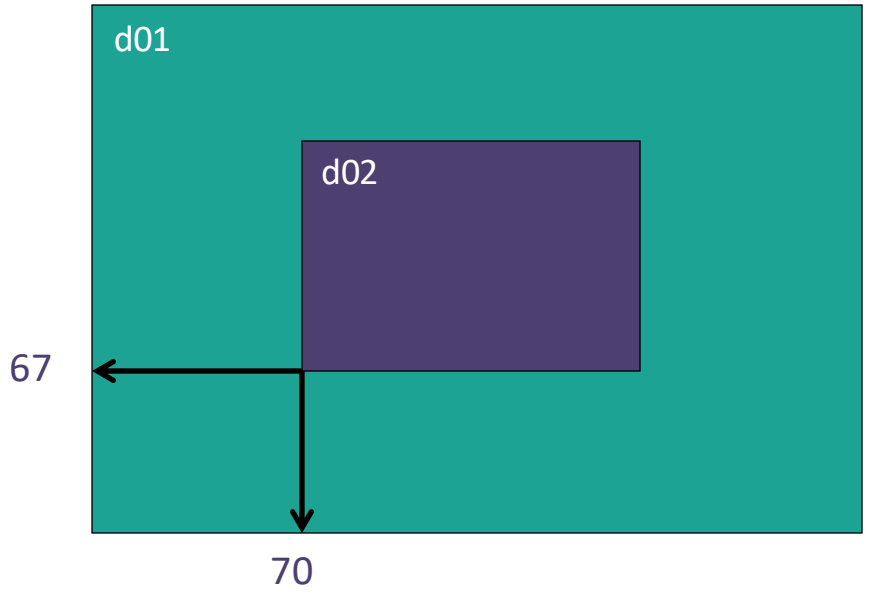
```
&geogrid
   parent_id           =   1,      1,
   parent_grid_ratio   =   1,      3,
   i_parent_start      =   1,     70,
   j_parent_start      =   1,     67,

   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:

The grid resolution ratio of the child to its parent

- must be an integer
- *recommended: odd ratios of 3:1 or 5:1*

i/j_parent_start:



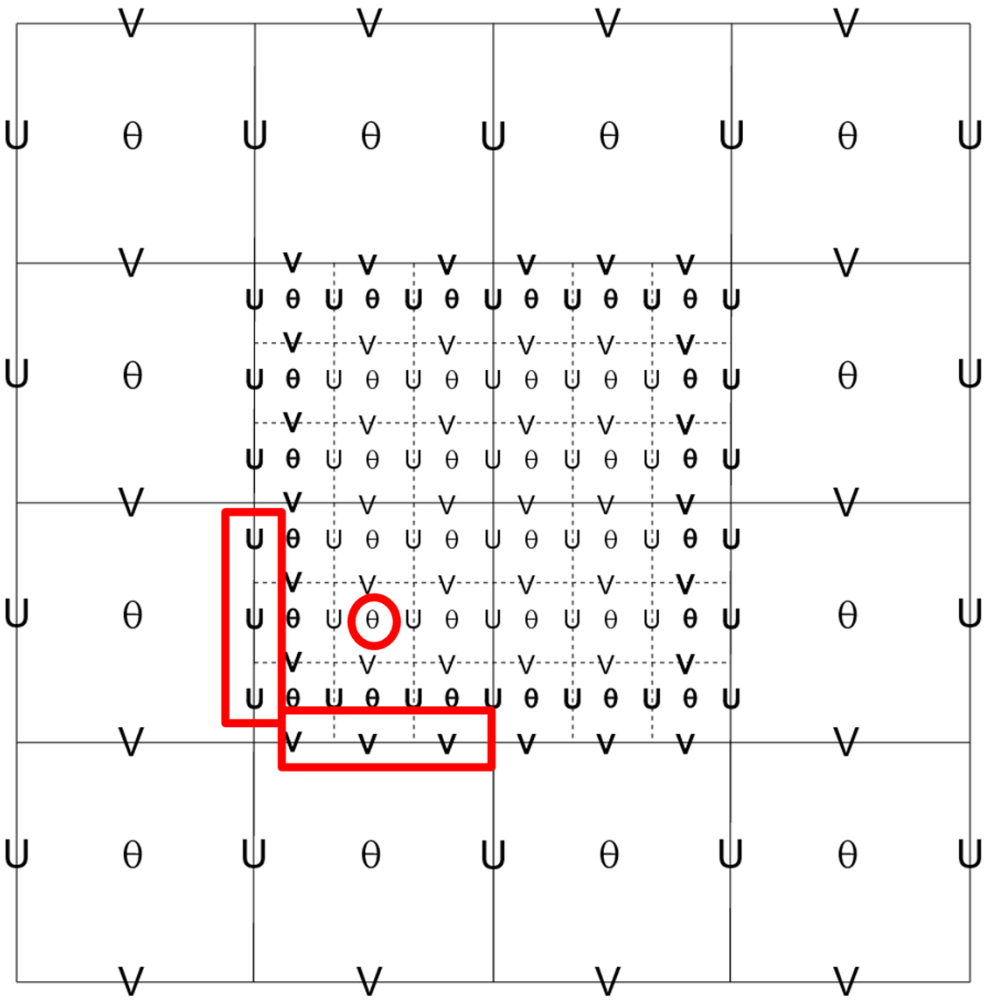
Odd Ratios for Feedback Option

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

3:1 grid ratio

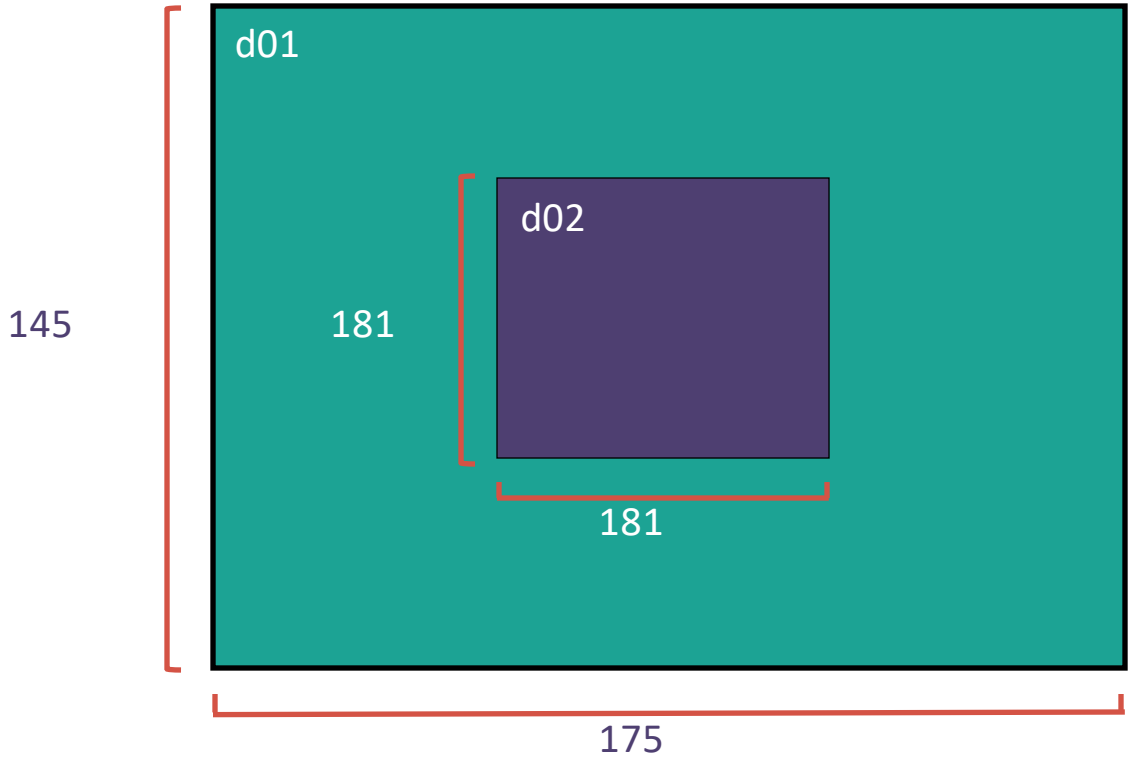


namelist.wps *&geogrid* for Nesting (4)

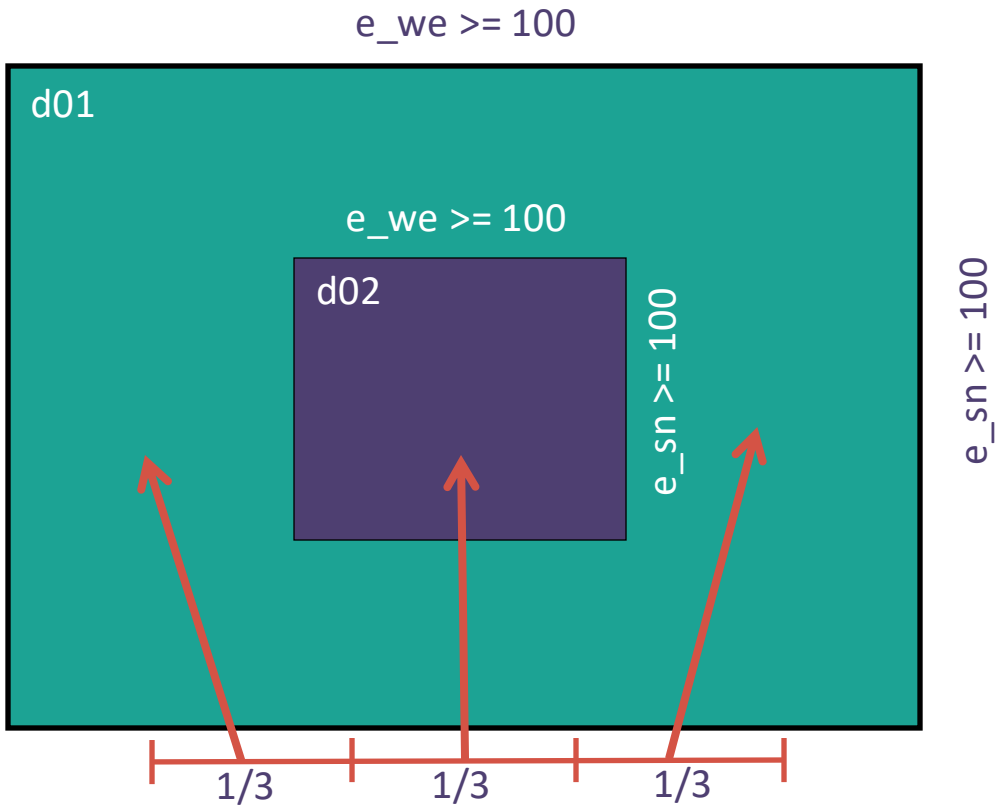
```
&geogrid
   parent_id             =   1,        1,
   parent_grid_ratio     =   1,        3,
   i_parent_start        =   1,       70,
   j_parent_start        =   1,       67,

   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



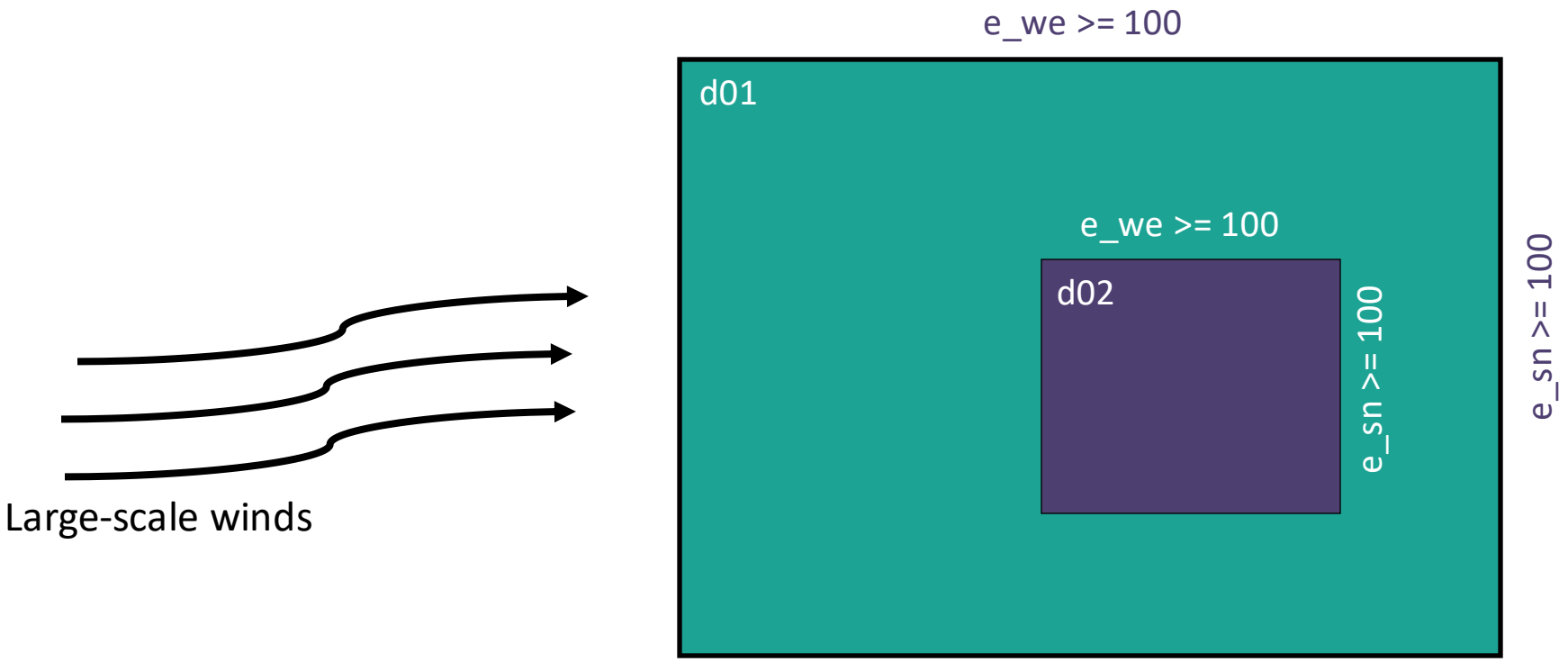
namelist.wps *&geogrid* for Nesting (5)



Notes:

- Domains should be >= 100x100
- Keep nest away from coarse domain - IN GENERAL – About 1/3 of the parent should remain around each side of the nest.

namelist.wps *&geogrid* for Nesting (5)

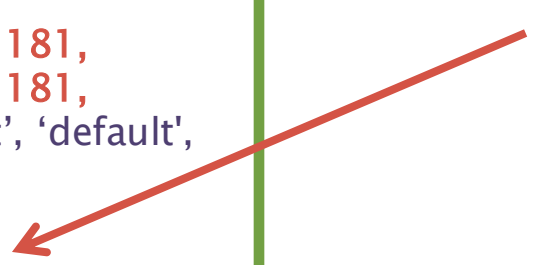


Notes:

- Domains should be >= 100x100
- Keep nest away from coarse domain - IN GENERAL – About 1/3 of the parent should remain around each side of the nest.

namelist.wps *&geogrid* for Nesting (6)

```
&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”

namelist.wps Final Notes

```
&ungrib
 out_format =       'WPS',
 prefix =           'FILE',
/

&metgrid
 fg_name =          'FILE'
 io_form_metgrid = 2,
/
```

&ungrib and &metgrid

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

Nesting Set-up for namelist.input

namelist.input *&time_control* for Nesting

```
&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

/
```

start/end date/times:

These values *typically* will be the same for all domains

history_interval:

How often history is written out.

*E.g., may choose to have more frequent output time for nests

frames_per_outfile:

The number of history intervals in a single file.

Time & 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 met_em* file
10800 = 3-hourly input data

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

history_interval:
Frequency (in simulation mins) 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 the example above, if it's set to 1, you should get a wrfout file for each simulation hour.

namelist.input *&domains* for Nesting (1)

```
&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                     = 45,    45,    45,
 p_top_requested            = 5000,
 num_metgrid_levels         = 32,
 num_metgrid_soil_levels    = 4,
 dx                         = 30000,
 dy                         = 30000,
 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:

# of vertical levels.

All columns usually have the same value

namelist.input *&domains* for Nesting (1)

```
&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,
 feedback                 = 1,
/
```

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

feedback:

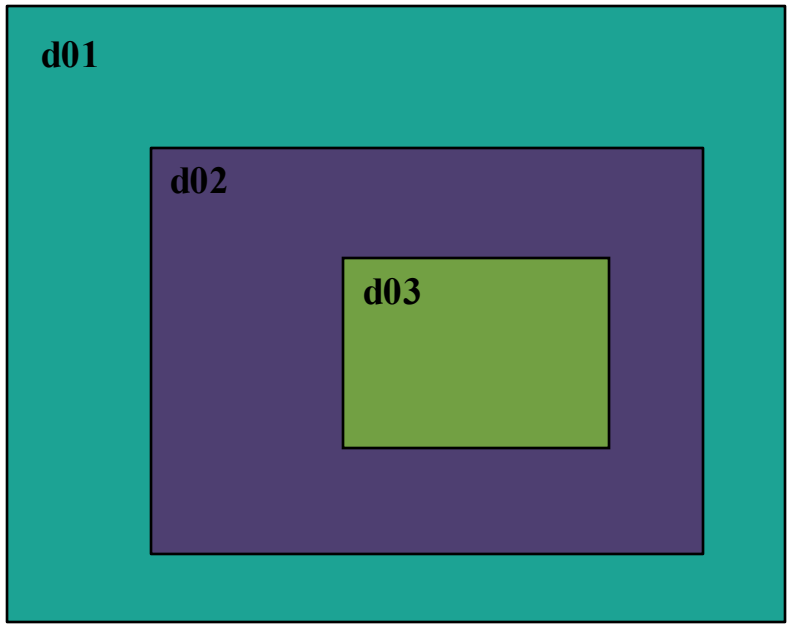
Whether a nest will overwrite parent results

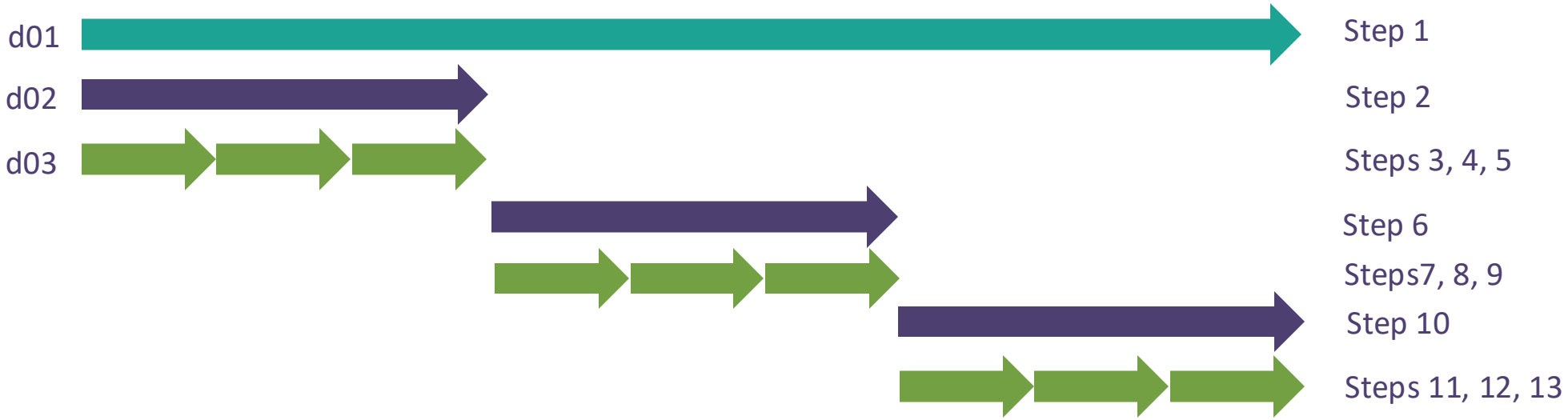
- 2-way nesting: feedback = 1
- 1-way nesting: feedback = 0

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

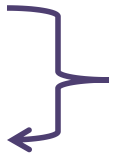




Namelist.input *&physics* for Nesting

- You should 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

- Use same values for physics calling frequency parameters (for each domain)
  - 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)

Namelist.input *&physics* for Nesting

- You should use the same physics options for all domains for all schemes
  - **Exceptions**:
    - cumulus_scheme (cu_physics): Can turn off for a nest that has a grid distance of only a few kilometers
    - Can turn off PBL scheme for resolutions close to 100 m

Where should you start?

Namelist templates and descriptions provided in test/em_real

- **README.namelist**
- **examples.namelist**

Not all namelist options are domain-dependent. If in doubt:

- Check **Registry files** (found in WRF/Registry*/)*

  ** grep for parameter names – look for "max_dom" (max_dom indicates a value is expected for each domain)*

Rule of thumb: If default namelist only has 1 column, don't add values for other columns!

Running WPS & WRF for Nested Domain

Use same executables for running with a single domain

WPS Output

- geogrid.exe : **`geo_em.d01.nc`**, **`geo_em.d02.nc`**, etc.
- ungrib.exe : same as single domain – not domain dependent
- metgrid.exe : **`met_em.d01*`**, **`met_em.d02*`** , etc.

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)

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
  - Based on computational allowance
- 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*

Thank you!