WRF-NMM Nesting (One-way Static)

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Overview

- Generic nesting basics
  - What is a nest, and why bother using one?
  - A few definitions (static, one-way)
- Details of WRF-NMM nesting
- Nest specification with the model namelist

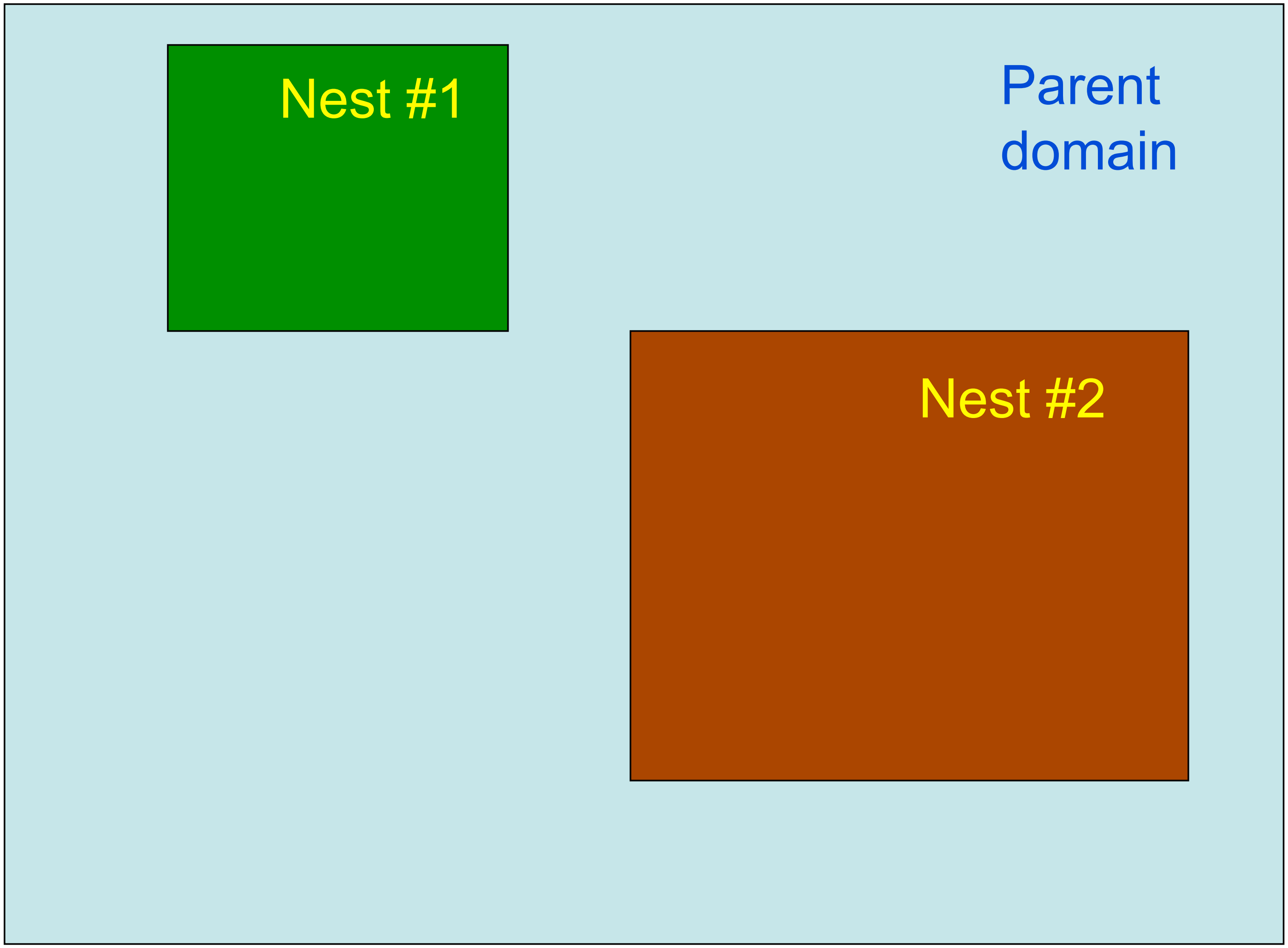
Nesting basics

- A nest is a finer-resolution model run embedded within a coarser-resolution (parent) model run, and run simultaneously with the parent domain.
- The nest covers a portion of the parent, and is driven along its lateral boundaries by the parent domain.
- Nesting enables running at finer resolution without:
  - Running at uniformly high resolution over a large region (computationally expensive!)
  - Running at high resolution over a single small domain (inferior temporal/spatial definition to LBCs)

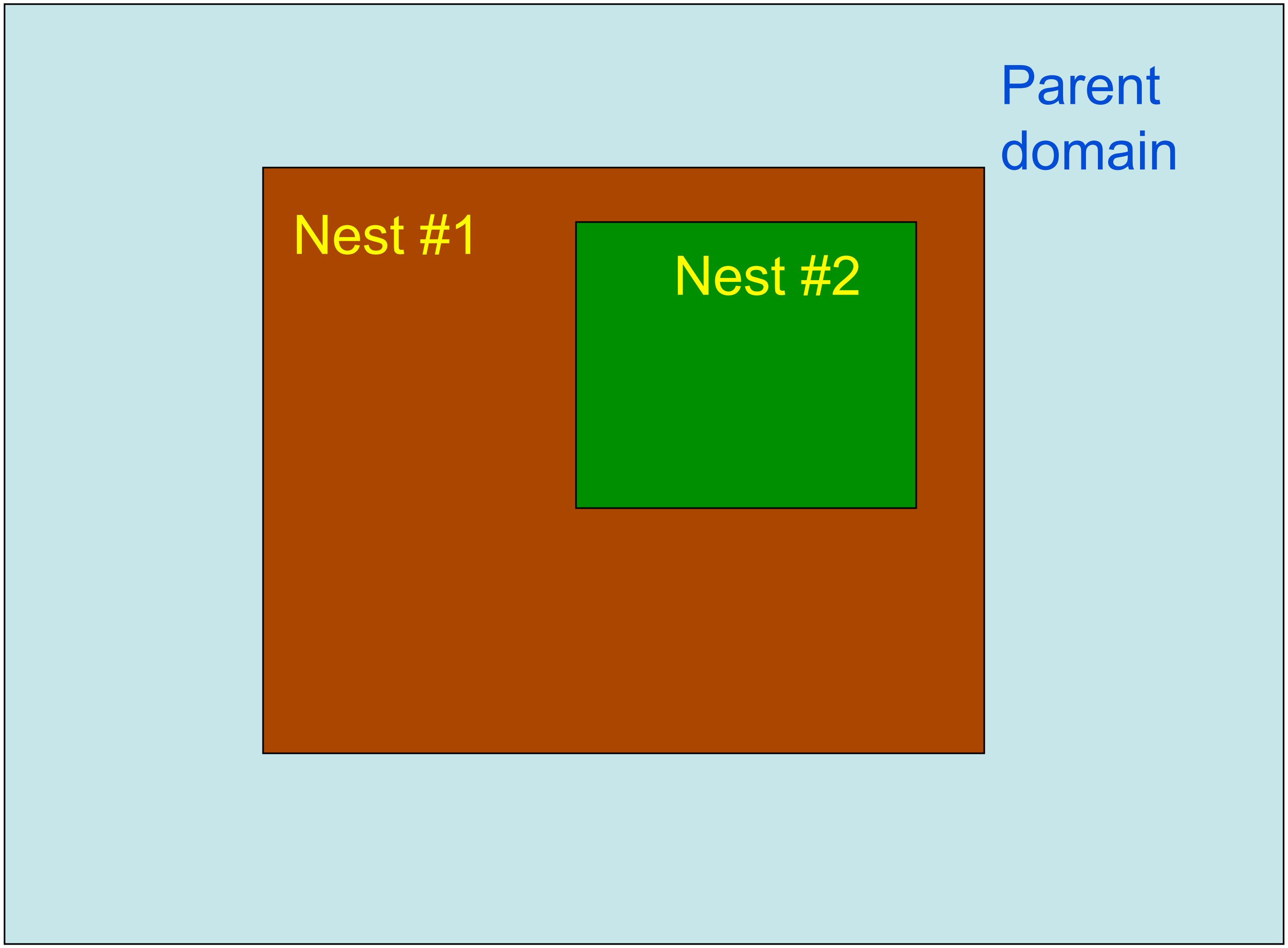
Nesting basics

- The focus here is on static, one-way nesting:
  - Static: the nest location is fixed in space, in contrast to a “moving nest” as might be used in an application such as hurricane modeling.
  - One-way: Information exchange between the parent and the nest is strictly downscale. The nest solution does not “feedback” on the coarser parent’s solution.

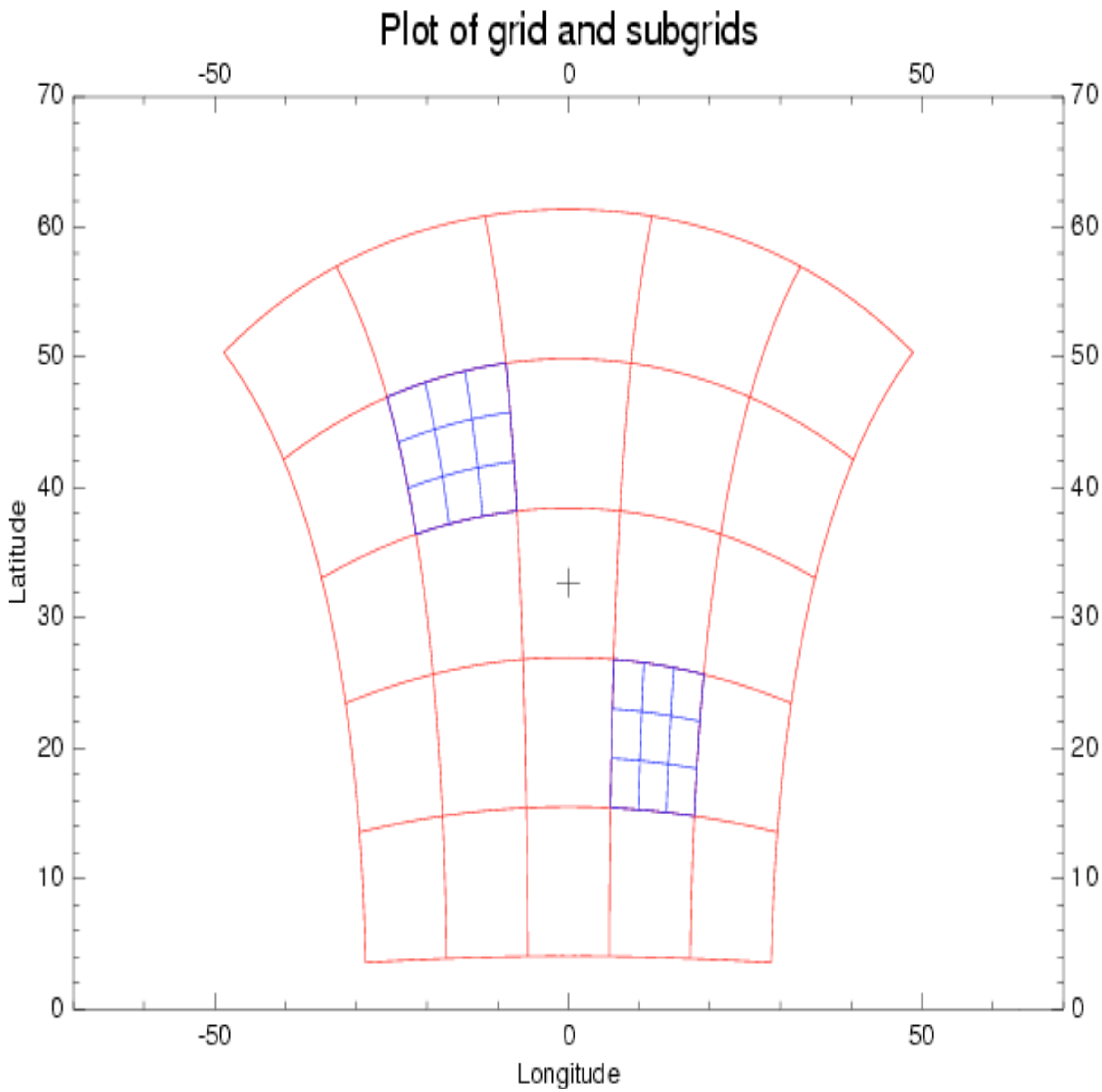
Two nests on the same “level” with a common parent domain



Two levels of nests, with nest #1 acting as the parent for nest #2



Nesting schematic



WRF-NMM specifics: Telescopic E-Grid

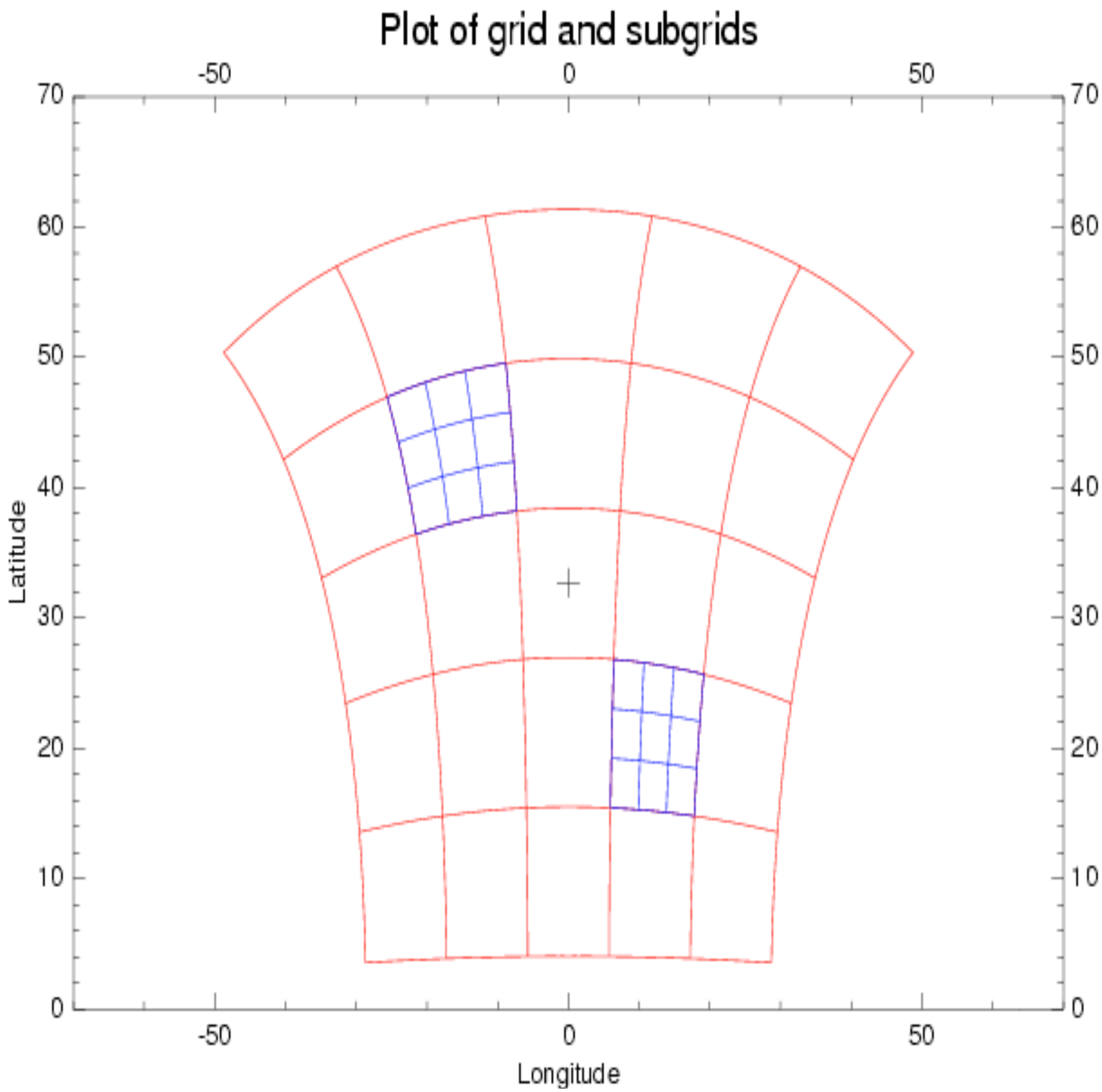
- Interpolations are done on the rotated lat-lon projection, and the reference lat-lon of the nest coincident with the centre of the parent domain.

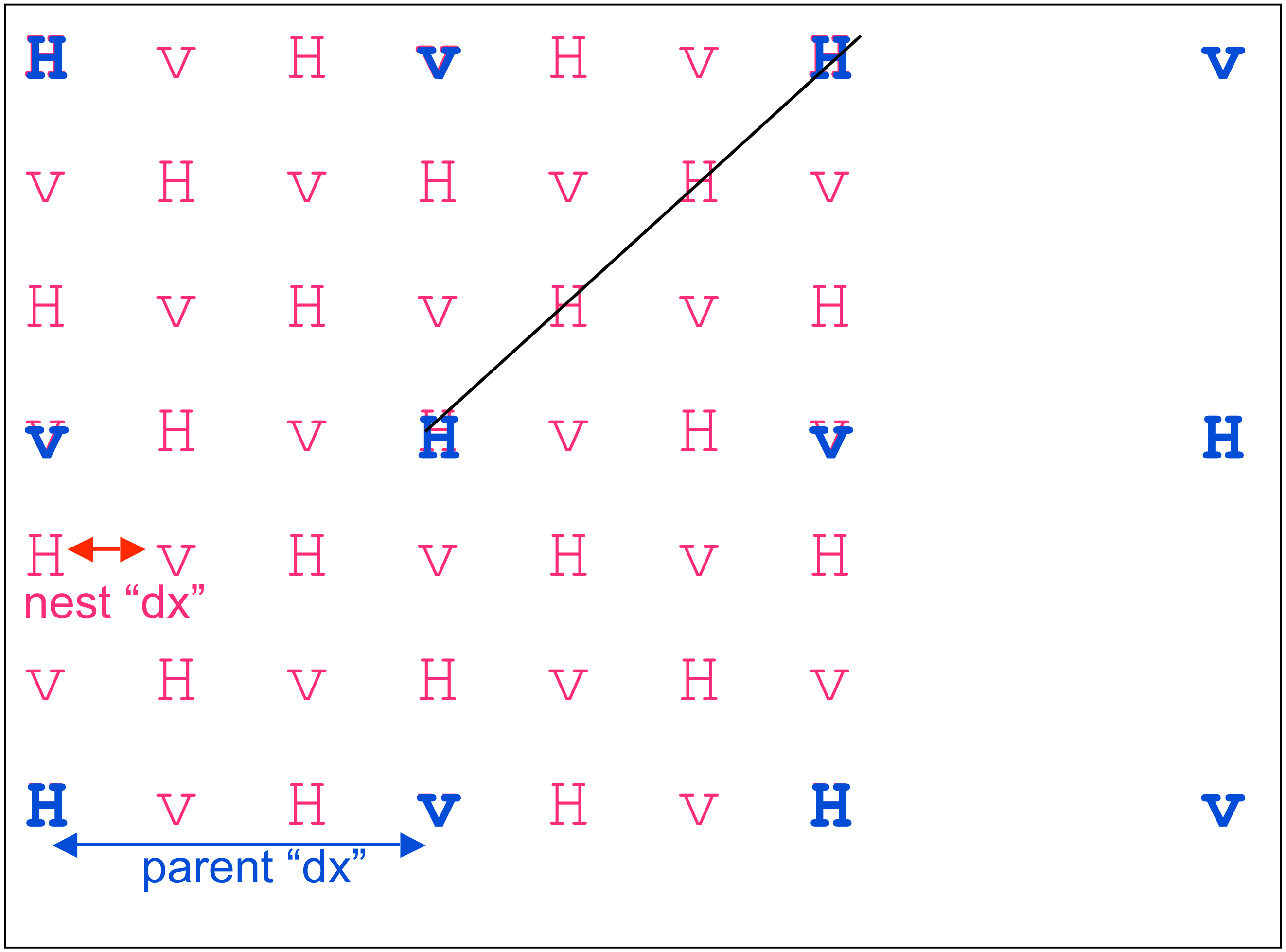
- Thus the nested domain can be moved anywhere within the parent domain, yet the nested domain lat-lon lines will coincide with the lat-lon lines of the parent domain at integral parent-to-nest ratios.

- Coincident parent/nest grid points eliminates the need for more complex, generalized remapping calculations available in the WRF software, and is expected to enhance distributed memory performance and portability of the modeling system.

- This grid design was created with moving nests in mind, but applies to static nesting as well.

Nesting schematic



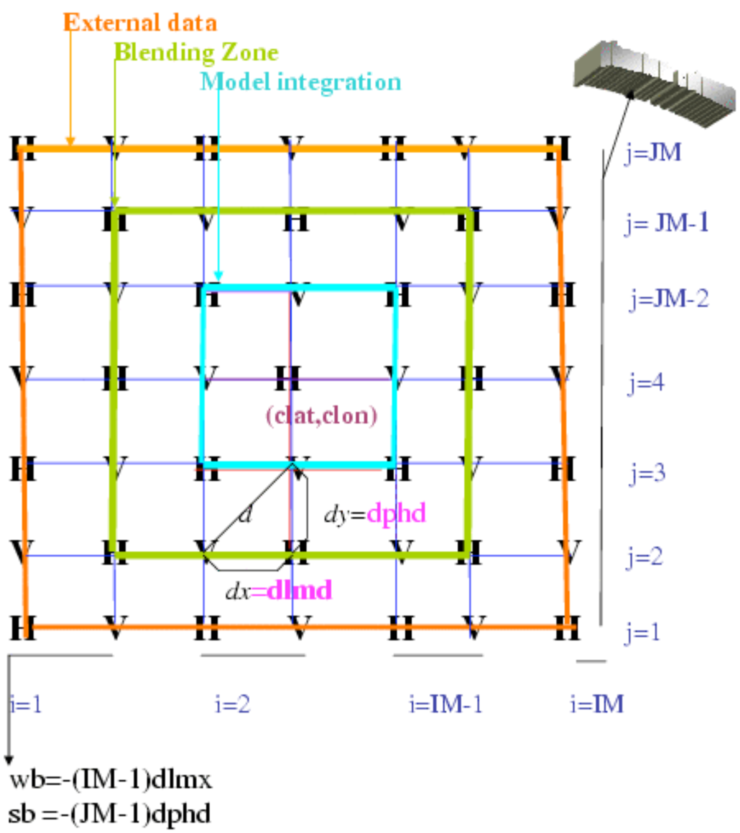


- An odd grid ratio introduces parent/nest points being coincident, and a 3:1 ratio is preferred as it has been extensively tested.

WRF-NMM specifics: Initial Conditions

- Simple bilinear interpolation of the parent initial conditions is used to initialize all meteorological fields in the horizontal on the nest (a single wrfinput_d01 file covers the parent and any nests).
- A nearest neighbor approach is adopted for prescribing most of the land state variables.
- Topography and the land-sea mask are redefined over the nested domain using the appropriate “nest level” of the WPS or wrfsi static dataset.
- Quasi-hydrostatic mass balancing is carried out after introducing the high-resolution topography (this process will be described in more detail later).

WRF-NMM specifics: Nested LBCs



* Given wb,sb, clat and clon, the above rotated lat-lon grid system can be transformed to a lat-lon grid system.

- Nest boundaries generally are treated in the same way as the standard parent domain boundaries:
  - outermost row is prescribed
  - two rows in from boundary is freely integrating
  - in between is a blending zone (average of outermost and freely integrating points)
- The one key difference is frequency of boundary updates: *nested boundaries are updated at every time step of the parent domain*.

WRF-NMM specifics: Mass balancing for LBCs

- The parent domain geopotential height (Z), temperature (T) and moisture (q) all are vertically interpolated (using cubic splines) from the hybrid surfaces onto standard isobaric levels.
- Using horizontally interpolated information of the height field from the parent domain, and high resolution topography over the nested domain, mass is adjusted and revised hybrid surfaces are constructed.
- T and q which have been horizontally interpolated to the nest domain and are on standard isobaric levels are then vertically interpolated onto the new hybrid surfaces.
- The approach may seem to be involved, yet, as seen later, produces an effective way of updating the nest interface without much distortion or noise even while moving the telescopic nest.

WRF-NMM specifics: namelist.input

- At the namelist level, nesting details are controlled by a few special variables that specify grid ratios and parent/nest relationships.

- The discussion here focuses on the namelist variables controlling the mechanics of nesting, and ignores elements controlling other aspects of the model (e.g., physics packages).

```
&domains
 max_dom        = 2,
 grid_id        = 1,      2,
 parent_id      = 0,      1,
```

How many total domains, including the parent (and thus how many columns in the namelist are relevant).

WRF-NMM specifics: time specification

```
&time_control
 start_year     = 2005,  2005,
 start_month    =   07,    07,
 start_day      =   06,    06,
 start_hour     =   06,    12,
 start_minute   =   00,    00,
 start_second   =   00,    00,
 end_year       = 2005,  2005,
 end_month      =   07,    07,
 end_day        =   11,    11,
 end_hour       =   06,    00,
 end_minute     =   00,    00,
 end_second     =   00,    00,
```

The starting and ending times can be different for the nest(s) than for the parent, but the nest must fit into the time window defined for the parent.

WRF-NMM specifics: history file output

```
&time_control
history_interval        = 360,   60,
frames_per_outfile      = 1,      1,
```

The WRF-NMM model produces separate output (history) files for the parent and for each nest.

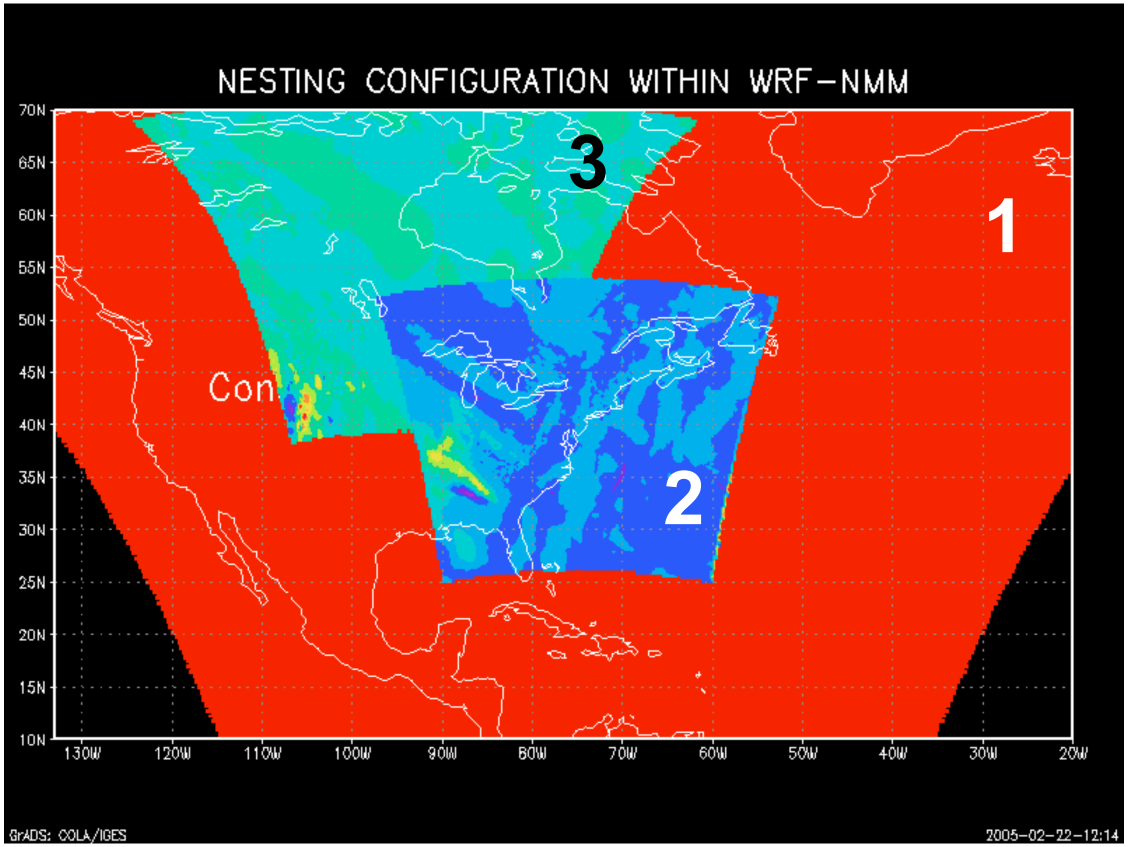
The history filenames are wrfout_d01_* for the parent, and wrfout_d02_*, wrfout_d03_*, … for the nested domain(s).

The history output can be written at different frequencies for each nest.

WRF-NMM specifics : Specifying multiple domains

Option 1: Both grid 2 and grid 3 are children of grid 1.

```
&domains
 max_dom    =  3,
 grid_id     = 1,     2,     3,
 parent_id   = 0,     1,     1,
```

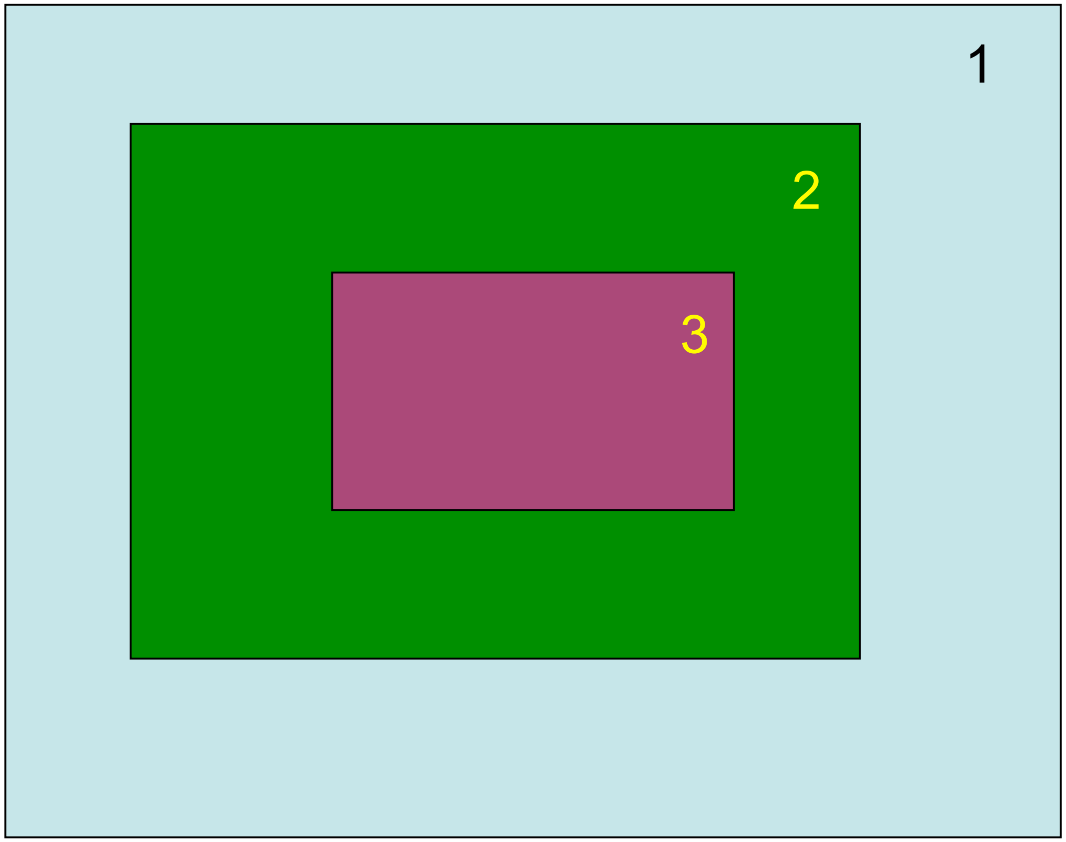


Overlapping domains are only possible with one-way nesting!

WRF-NMM specifics: Specifying multiple domains

Option 2: Grid 2 is a child of grid 1. Grid 3 is a child of grid 2.

```
&domains
 max_dom    =  3,
 grid_id     = 1,     2,    3,
 parent_id   = 0,     1,    2,
```



WRF-NMM specifics: Domain configuration

```
&domains
 time_step                    = 60,
 time_step_fract_num   = 0,          X
 time_step_fract_den    = 1,
.
.
.
 parent_grid_ratio           = 1,          3,
 parent_time_step_ratio=  1,          3,
 dx                               = .18,
0.06,                                        X
 dy                               = .18,
0.06,
```

time_step for the nest(s) does not need to be specified; it is derived from the parent time_step and the ratio specified below.

The nest “dx” and “dy” values are ignored and are not required (the 3:1 ratio specified by parent_grid_ratio computes the nest dx and dy within the code).

WRF-NMM specifics: Domain configuration

```
&domains
grid_id         = 1,    2,    3,
parent_id       = 0,    1,    2,
i_parent_start  = 0,    8,   13,
j_parent_start  = 0,    3,    6,
```

The i_parent_start and j_parent_start entries fix the SW corner of the nest grid to the specified (I,J) value of its parent domain.

In this example, the first nest "starts" at (8,3) of the parent domain, and the second nest starts at (13,6) of the first nest.

Static nesting performance

- The size of the nested domain may need to be chosen with computing performance in mind.
- Assuming a 3:1 ratio, the higher-resolution nest will require three times as many time steps to cover the same forecast length (time step 1/3 as long).
- If the same grid dimensions were used for the parent and nest, the combined system would take about 4X longer to run than the parent alone.

Static nesting performance

- Timings for a 12 h forecast, with a 51 x 92 parent and variously sized single nests:

- 70 s for 51x92 parent domain alone (no nest)
- 171 s for parent and nest combined (31x32 nest)
- 302 s for parent and nest combined (51x92 nest)
- 464 s for parent and nest combined (82x124 nest)
- 713 s for parent and nest combined (102x184 nest)

Advanced Nesting

Advanced Nesting

- Everything discussed to this point is included in the WRF Repository code and is a part of the code you will use in the practical sessions.

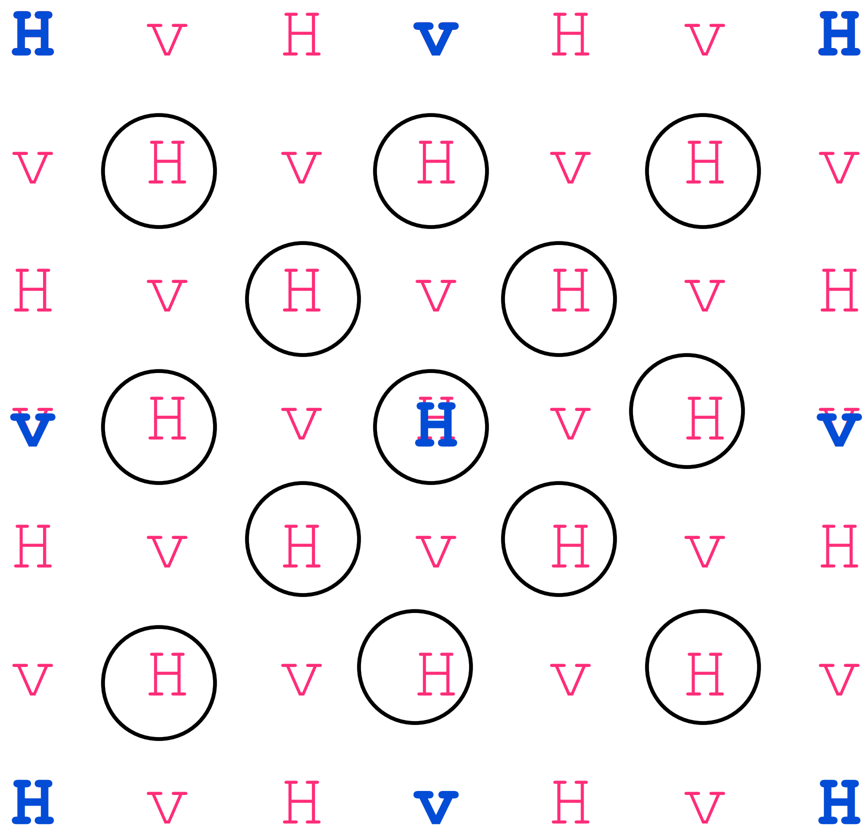
- Now we will look at two WRF-NMM nesting topics that were developed within older versions of the WRF software framework, and which are NOT YET a part of the up-to-date public release:

  – Two-way interactive static nesting
  – Moving nest

Advanced Nesting (cont)

- Current plan is for these nesting options to become available in a public release when the WRF-NMM transitions from the current IKJ indexed code to an IJK indexed code (hopefully next 6-12 months).

Two-Way Interactive Static Nest



A 13-point average of fields from the high resolution nest are weighted and fed back into the parent domain.

Currently, the weighting factor is 0.5 (50% parent, 50% of 13-point average from the nest)

Two-Way Interactive Static Nest

- The odd ratios (such as 3:1) are important with two-way nesting, as the feedback will only work with coincident grid points.

- Also, recall that overlapping nests are not allowed when there is feedback to the parent grid.

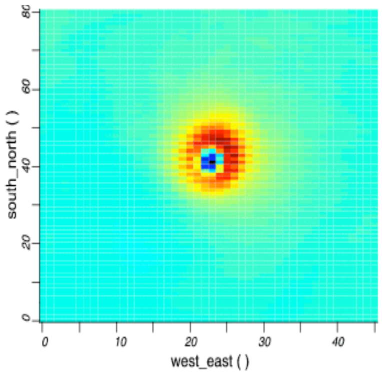
Moving nest runs

- Rather than being static and fixed in space, a moving nest will move and stay centered over a feature of interest.
- The WRF-NMM moving nest capability was developed with hurricane forecasting in mind, though other applications may be possible.
- Moving nest runs typically are two-way nested, but can also be run without feedback to the parent domain.

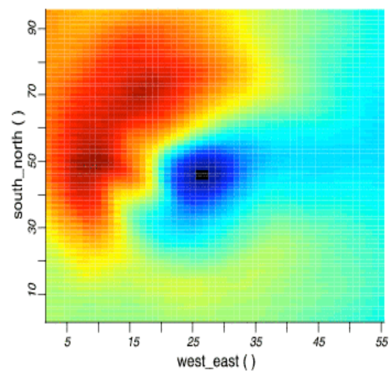
WRF-NMM GRID MOTION

- The moving nest is "set to sail" on the parent domain using a simple criterion based on variations in dynamic pressure.
- This dynamic pressure is a function both of perturbation pressure and wind speed, and is capable of tracking both strong and weak vortices.
- The so-called “stagnation point” of dynamic pressure defines the center of the storm (Gopalakrishnan et al 2002, MWR.)

Strong vortex



Weak vortex

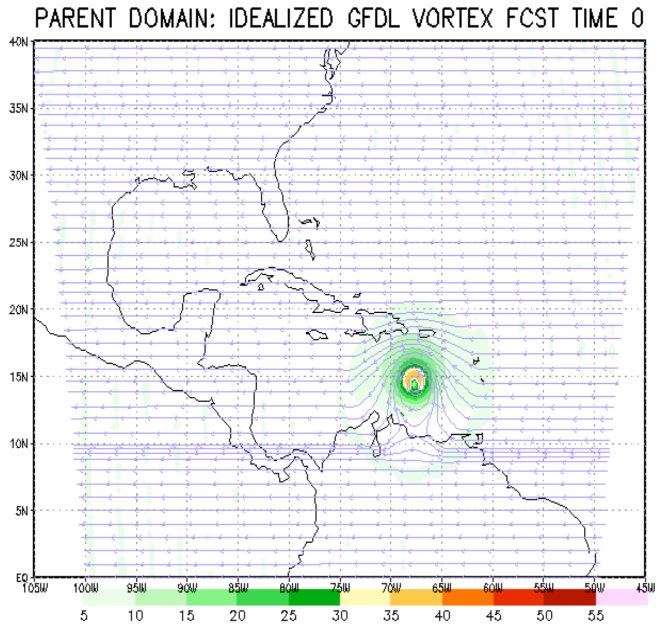


WRF-NMM GRID MOTION

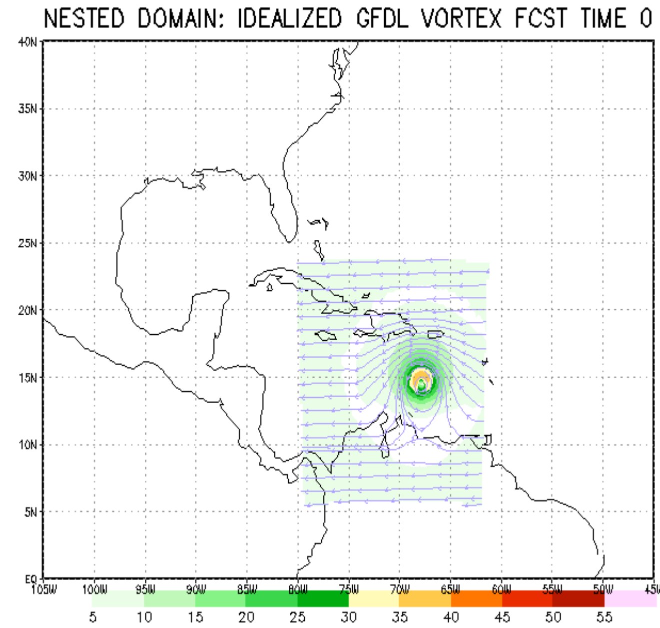
- As the nest moves, data are exchanged between the parent and the nest before and after grid motion.
- The same bilinear interpolation and mass balancing approach used with one-way nesting is used here, but only is applied to the leading edge of the nest moving into a new part of the parent domain.
- Moving a row or column at a time, the nest can stay centered over the storm while smoothly updating its fields.

GFDL IDEAL* VORTEX INITIALIZATION

Parent domain covering about 60° x 60° at 36 km resolution

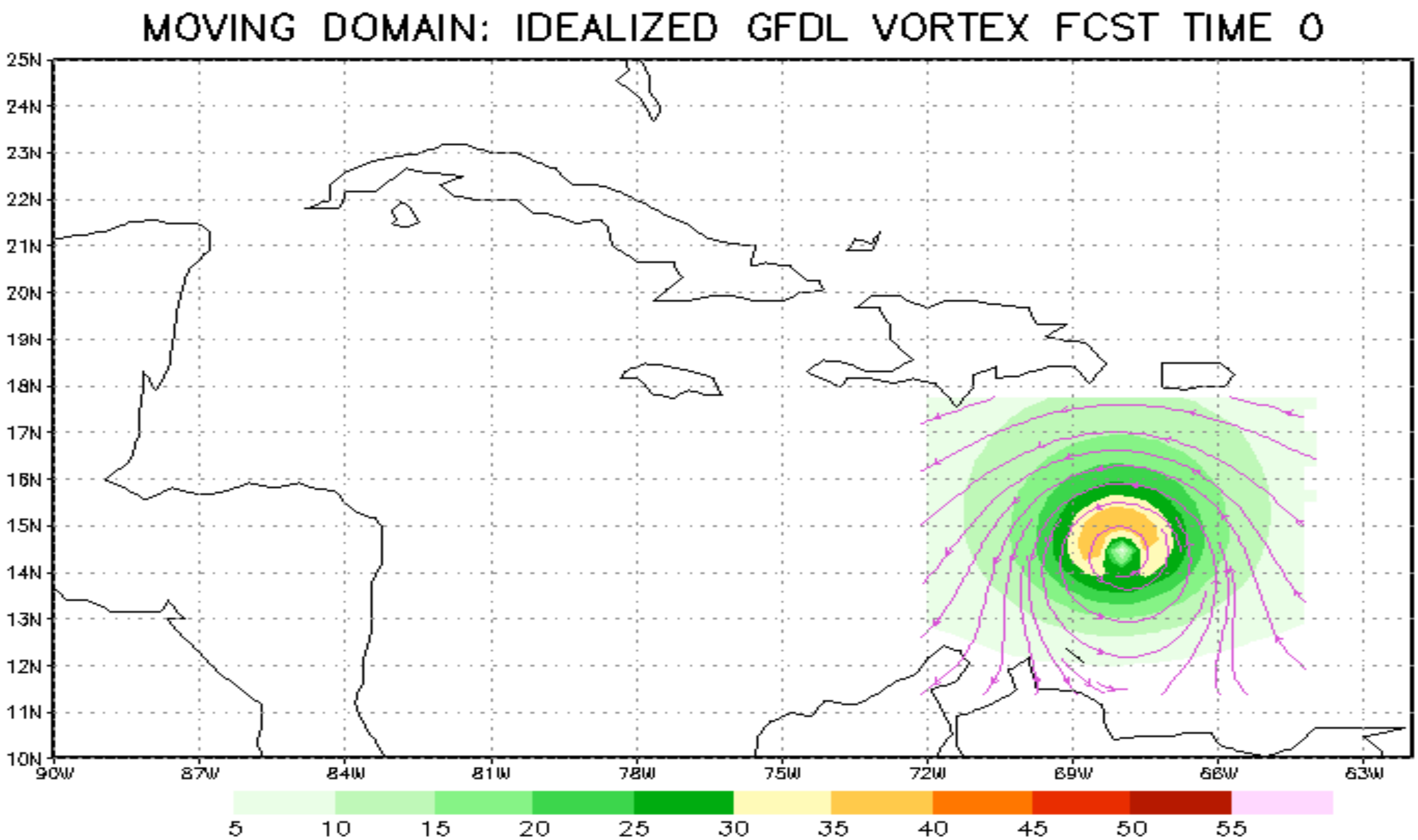


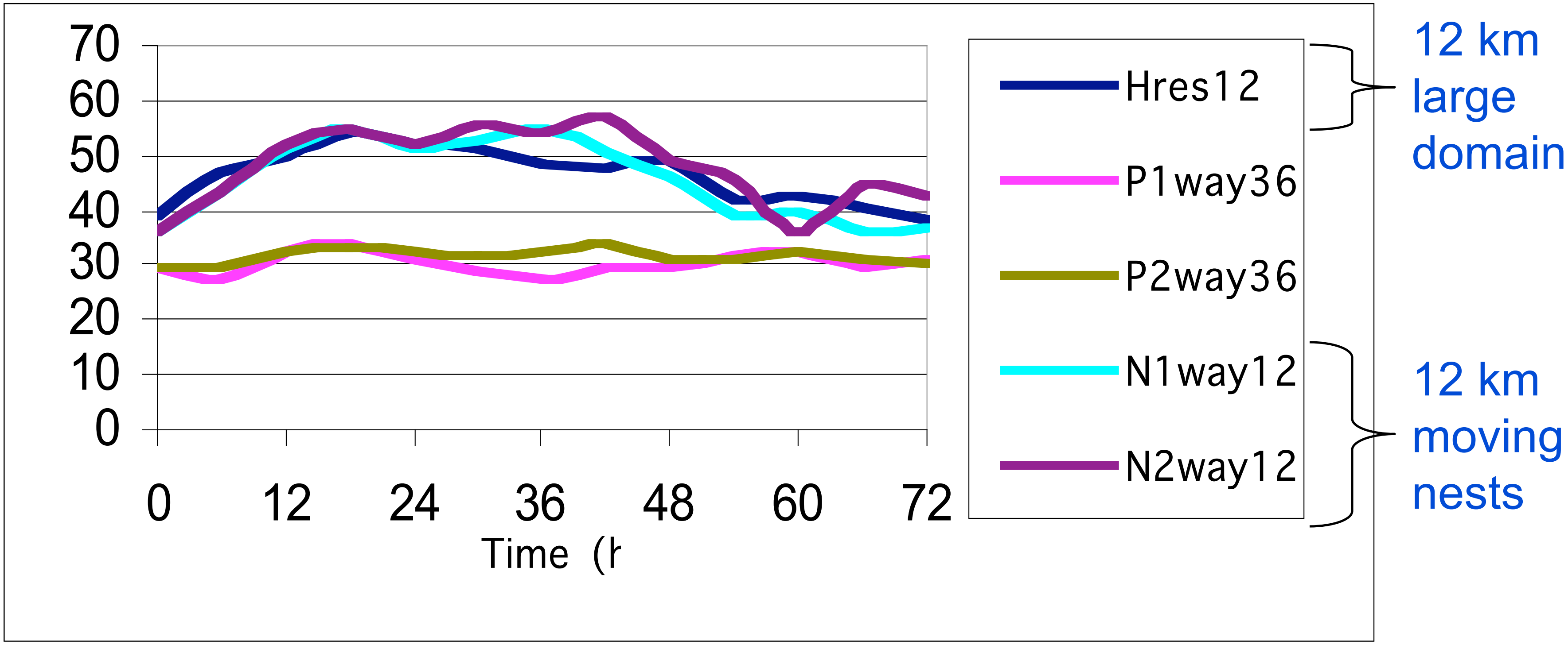
Static nested domain covering about 20° x 20° at 12 km resolution



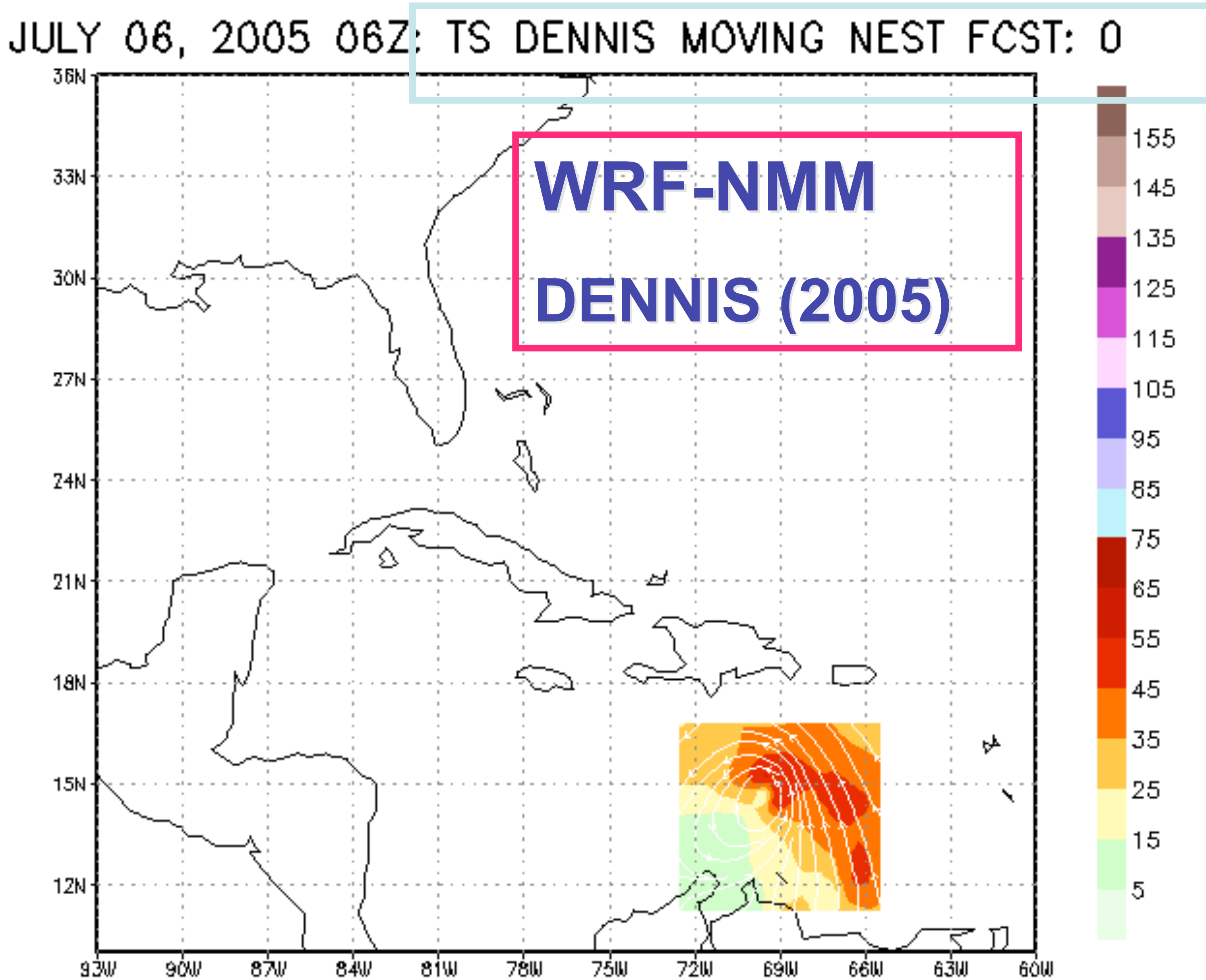
* The initial condition for this idealized case did not include topography and land. However, as in the case of a static, one-way nest, the code is general enough to take care of topography.

Moving domain covering about $7^0 \times 7^0$ at ~12 km resolution





Despite the small size of the nested domain, as long as the vortex is located in the center of the nest, we see the effect of lateral boundary diffusion to be limited and we are indeed able to hold on to the intensities!



JULY 06, 2005 06Z: TS DENNIS MOVING NEST FCST: 0
WRF-NMM
DENNIS (2005)
36N
33N
30N
27N
24N
21N
18N
15N
12N
93W
90W
87W
84W
81W
78W
75W
72W
69W
66W
63W
60W
155
145
135
125
115
105
95
85
75
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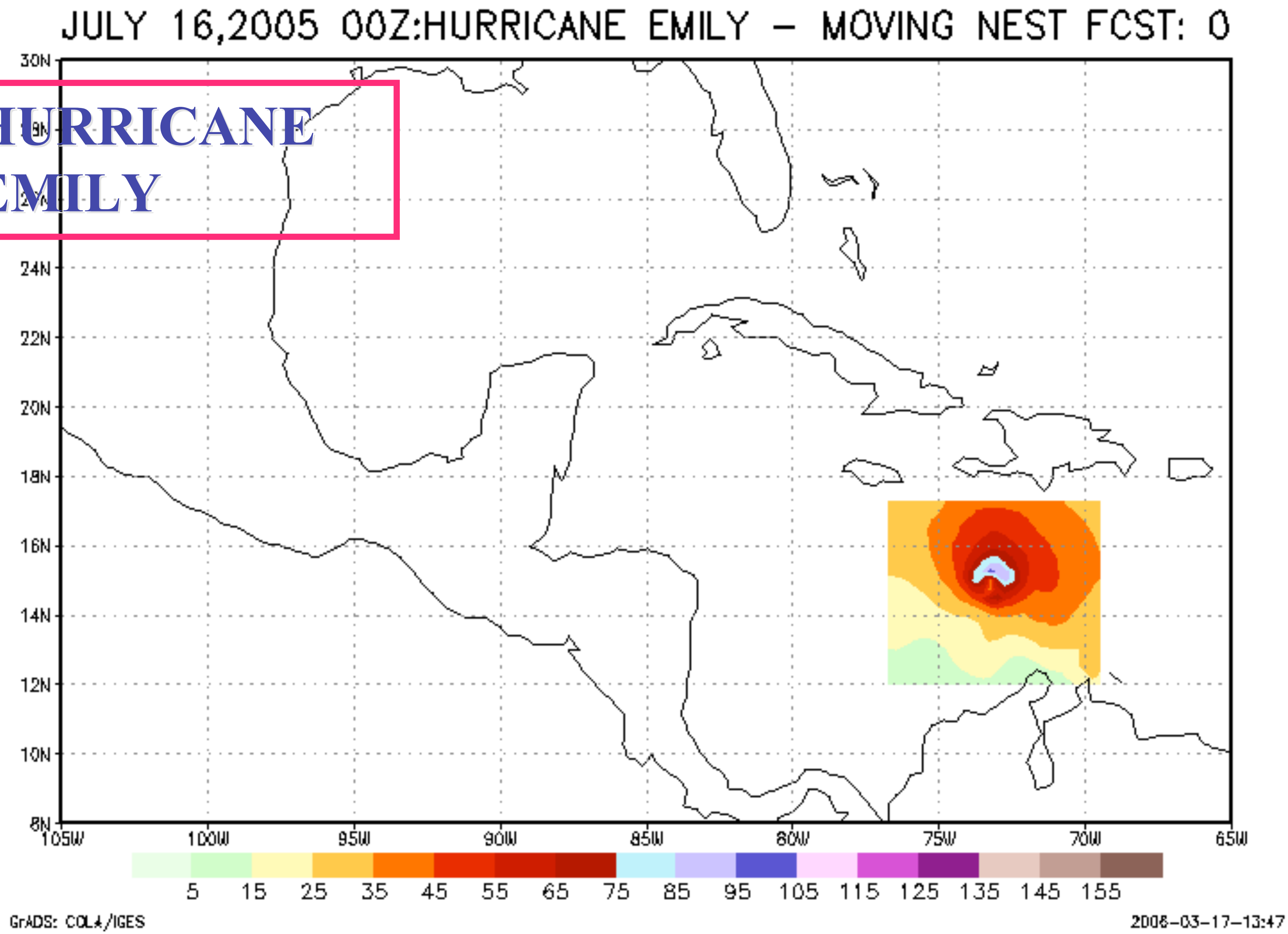
55
45
35
25
15
5

HURRICANE EMILY



WRF-NMM

Hurricane

Katrina