Lecture (16)

Grid Nesting and Mesh Refinement

تداخل وتنعيم الشبكات

16.1 Nested Grids

Some models are run with finer-resolution grids nested inside coarser-resolution grids within the same model. Grid nesting is used when computational limitations prohibit fine-resolution grids from covering the entire model domain. Nesting can be one-way or two-way, from the coarse-grid to the fine grid and from the fine-grid to the coarse-grid. In Figure 1, where the fine-grid covers the coarse-grid, the forecast variables for the coarse-grid are updated based on the fine-grid prediction.

The coarse-grid prediction provides boundary conditions on the nest interface for use in the fine-grid prediction. Advantages of the two-way nested grid include, fine-scale processes resolved on the finer grid are allowed to affect the larger-scale flow on the coarse grid.

This is important for numerical weather prediction because the small-scale processes in the atmosphere greatly influence the large-scale processes in the atmosphere. Since the predictions on coarse-resolution grids take less computer time and memory compared to fine resolution grids, the outermost boundary of the model can be moved far from the forecast region, while the fine-resolution domain remains small enough to run in real time. Moving nests are also common in the present models where a higher resolution nest can move with the phenomenon of interest (e.g., hurricane).

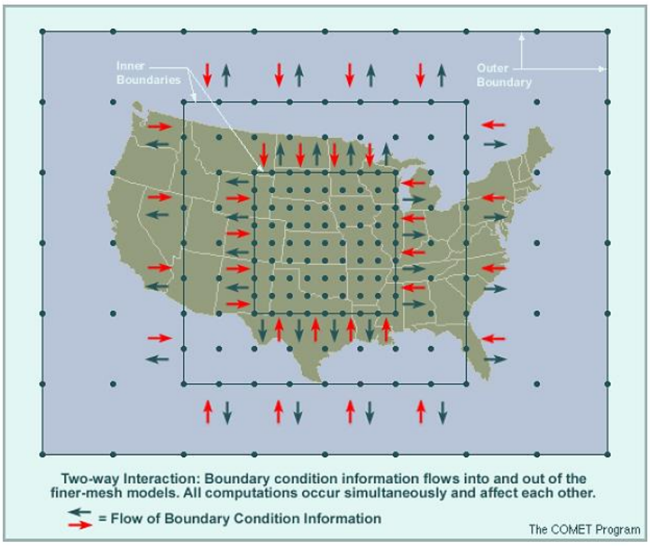

Figure 1. Example of a two way nested grid with coarse resolution outer domain and finer resolution inner domains. Staggering type is typically same for all domains. The arrows indicate direction of information exchange.

An example of staggered C grid with nesting is also shown in Figure 2.

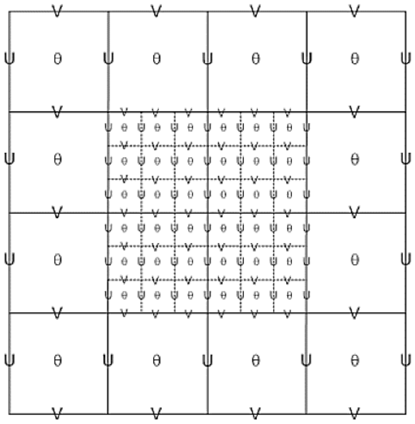

Figure 2. A portion of a nested grid with C grid staggering with 3:1 grid size ratio. The solid lines denote coarse-grid cell boundaries, and the dashed lines are the boundaries for each fine grid cell. The bold typeface variables along the interface between the coarse- and the fine-grid define the locations where the specified lateral boundaries for the nest are in effect.

16.2 Mesh Refinement

Adaptive Mesh Refinement (AMR) is a technique provides an attractive framework for atmospheric flows since they allow an improved resolution in limited regions without requiring a fine grid resolution throughout the entire model domain. It has all the advantages of a hexagonal grid with a C grid staggering and can be used for global (Figure 3a) and regional (Figure 3b) applications. Compared to traditional grid nesting, these meshes can cleanly incorporate both downscaling and upscaling effects. For example, Figure 14 shows selective mesh refinement based on terrain height. Note that the high terrains are accompanied by higher resolutions.

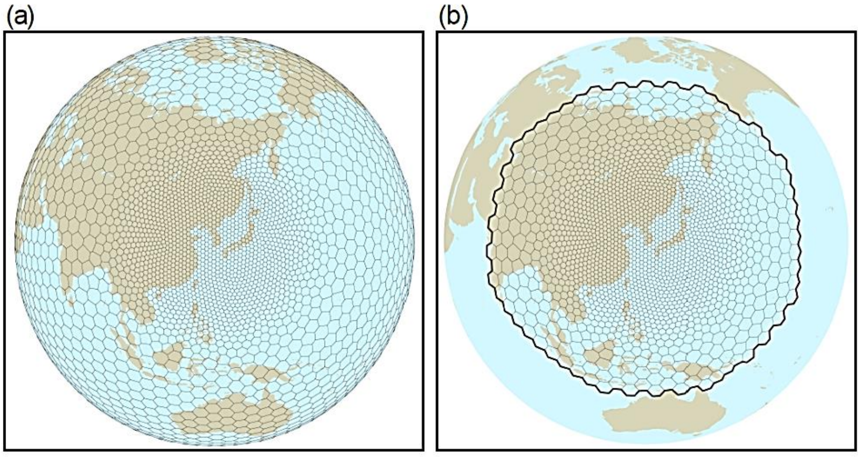

Figure 3. Variable resolution mesh at (a) global and (b) regional scale.

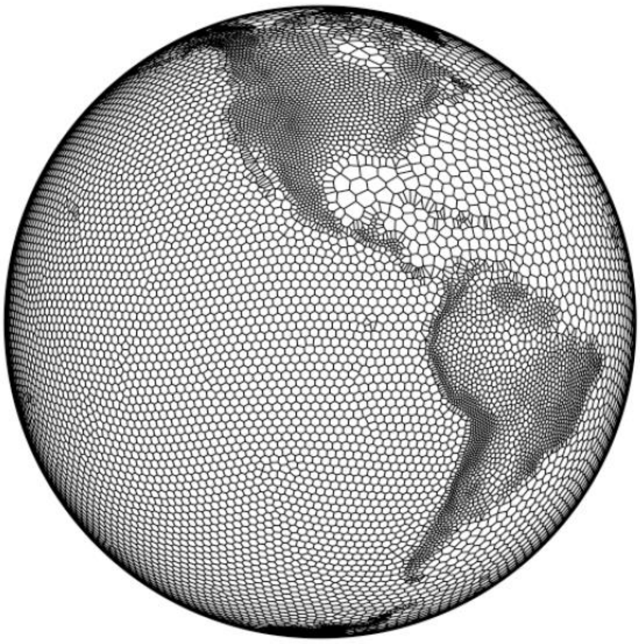

Figure 4. Selective mesh refinement for terrain height.

16.3 Parameterization and Grid-Spacing

Parameterization in a weather or climate model in the context of numerical weather prediction is a method of replacing processes that are too small-scale or complex to be physically represented in the model by a simplified process. This can be contrasted with other processes—e.g., large-scale flow of the atmosphere—that are explicitly resolved within the models. Example of the small processes include the planetary boundary layer, convective clouds, the atmospheric radiative transfer, and cloud microphysics.

Models with a grid spacing of 10 km or larger, which is roughly 10 to 20 times the size of the cumulus cloud, needs much finer resolution to resolve small cumulus clouds well.