FMS Overview and Nesting Support

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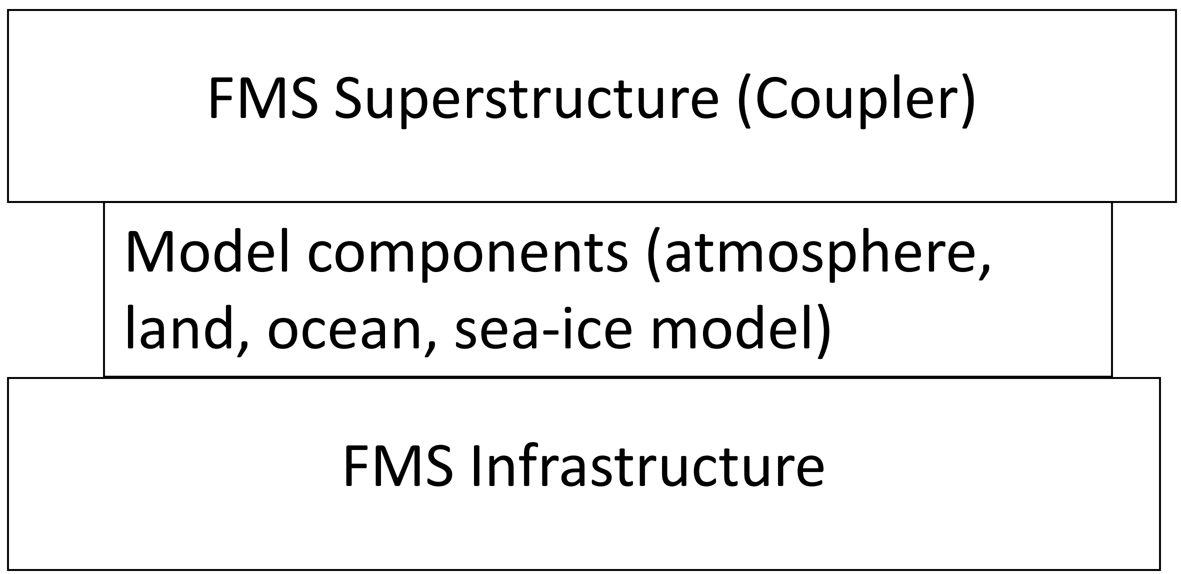
Outline

- FMS Overview
  - FMS Superstructure
  - FMS Infrastructure
- Status of FMS nesting support

What is FMS?

- A software framework for supporting the efficient development, construction, execution, and scientific interpretation of atmospheric, oceanic, and climate system models.
- A standardization of the interfaces between various component models to build a coupled model.
- http://www.gfdl.noaa.gov/fms

FMS Architecture



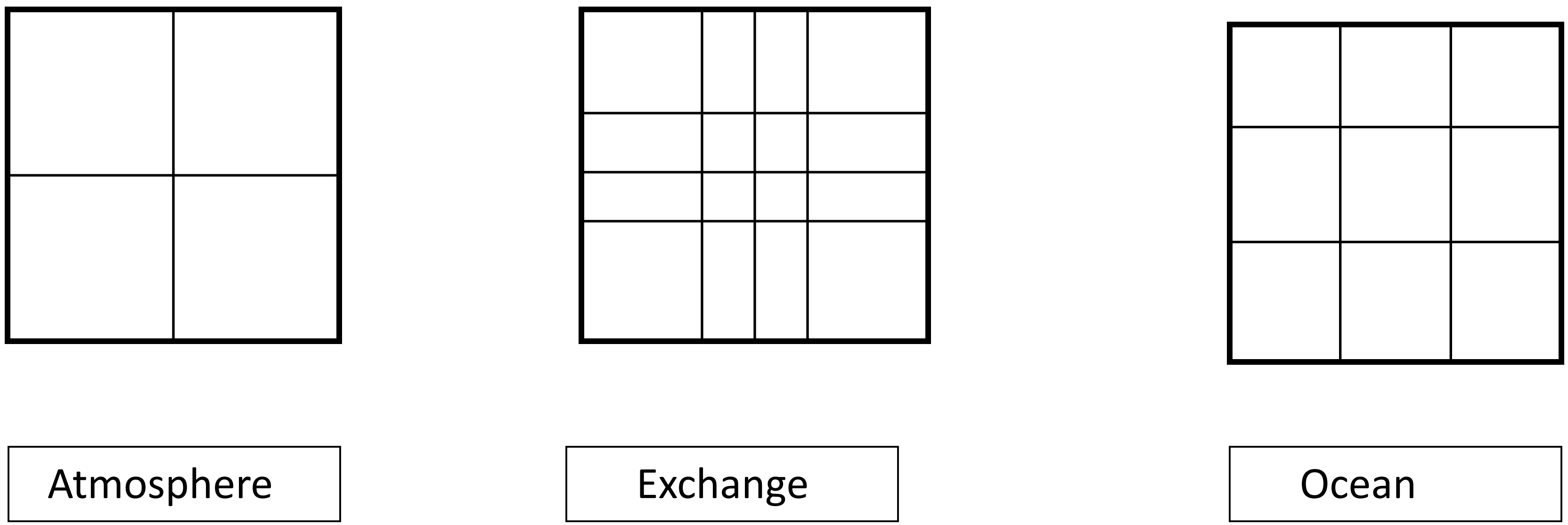
FMS Superstructure: Coupler

- Driver to run the earth system model.
- Encapsulated boundary state and boundary fluxes.
- Modular design: uniform interface to main calling program.
- Support for serial and concurrent coupling within single executable.
- Slow time step and fast time step for model integration.

Flux exchange

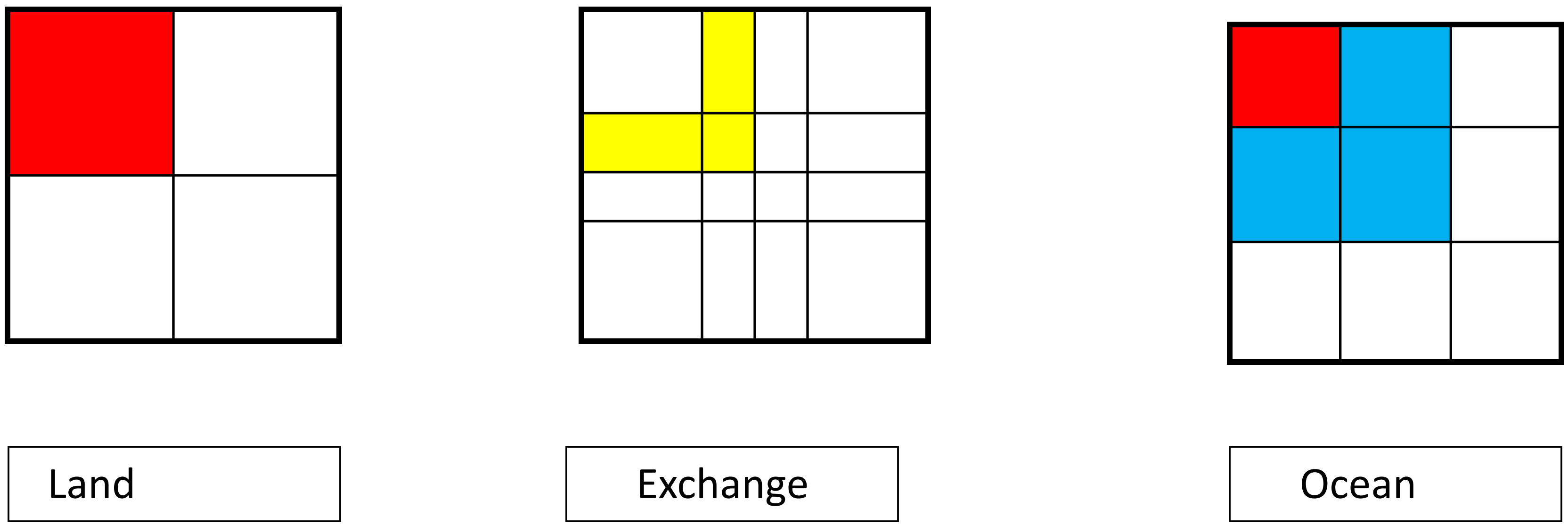
- Conservation: required for long runs.
- Resolution: no constraints on time steps and spatial grid of model components.
- Flux exchange are through exchange grid.
- Exchange grid: union of component model grids, where detailed flux computations are performed.
- Fully parallel: Calls are entirely processor-local: exchange software will perform all inter-processor communication.
- Modular design: uniform interface to main calling program.
- Three types of flux exchange: REGRID, REDIST and DIRECT.

Exchange grid



1. Each cell on Exchange grid belongs to one cell on each parent grid.
2. Flux exchange uses up to second order conservative interpolation.
3. All calls exchange local data. Data-sharing among processors is internal to the exchange software, and non-blocking.
4. All the exchange grids and weight information are pre-calculated using clip algorithm.

Exchange Grid: Mask problem



- An issue arises when land and sea-ice share a boundary. Land and Sea-ice grid have their own land-sea mask. Exchange grid cells need to be uniquely assigned to a single component.
- In FMS, land grid is clipped to match the land-sea mask of sea-ice grid. Hence land grid may have partial cell.

Flux exchange Algorithm

- Up to second-order conservative Remapping scheme.
  If destination cell k overlaps N cells on the source grid, the remapping algorithm will be

$$\overline{F}_k = \frac{1}{A_k} \sum_{n=1}^{N} \int_{A_{nk}} f_n \, dA$$

$$f_n = \bar{f}_n + \nabla_n f \bullet (\vec{r} - \vec{r}_n)$$

Where $\overline{F}_k$ is the area-averaged flux over destination destination cell k, f is the flux on the source grid, A_k is the area of cell K, $\vec{r}_n$ is the centroid of cell n defined by

$$\vec{r}_n = \frac{1}{A_n} \int_{A_n} \vec{r} \, dA$$

Reference: "First- and Second-Order Conservative Remapping Schemes for Grids in Spherical Coordinates", Philip Jones, Monthly Weather Review, 127, 2204–2210. doi: 10.1175/1520-0493(1999)

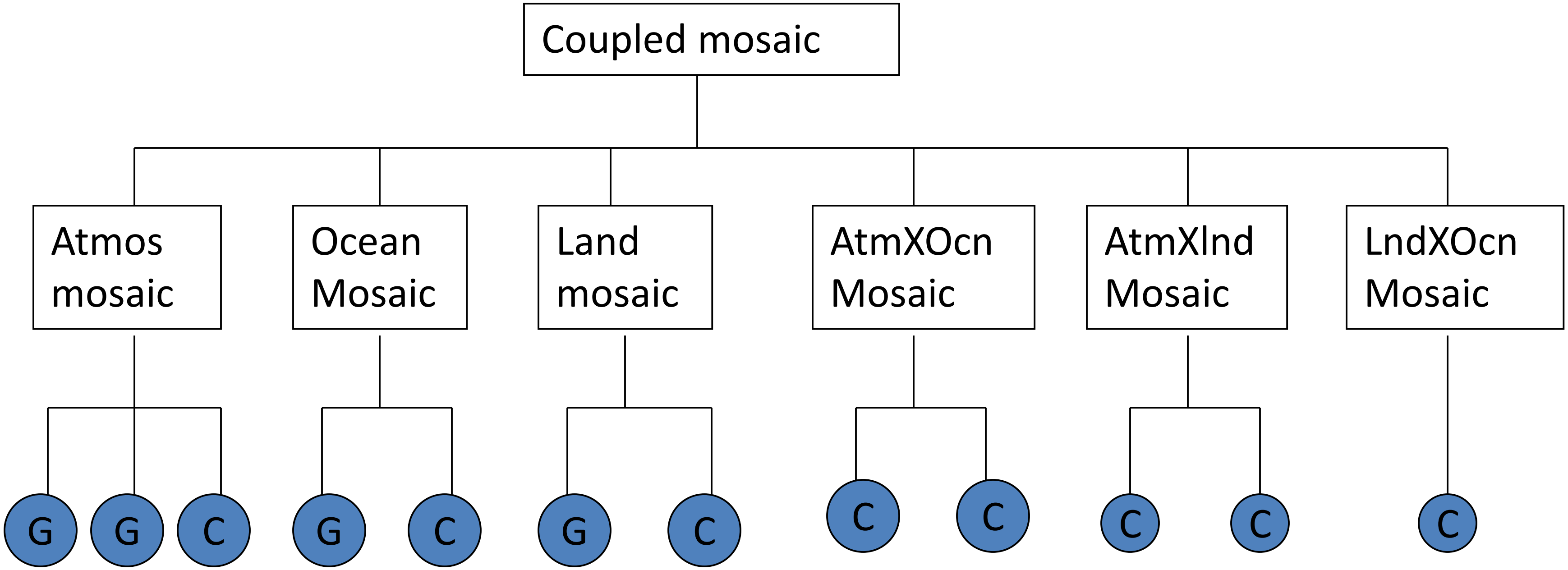
FMS shared infrastructure

- Mosaic Grid --A standard for the description of grids used in earth system models.
- MPP modules communication kernels, domain decomposition and update, parallel I/O.
- Diagnostics manager Runtime output of model fields.
- Data override Runtime input of model fields.

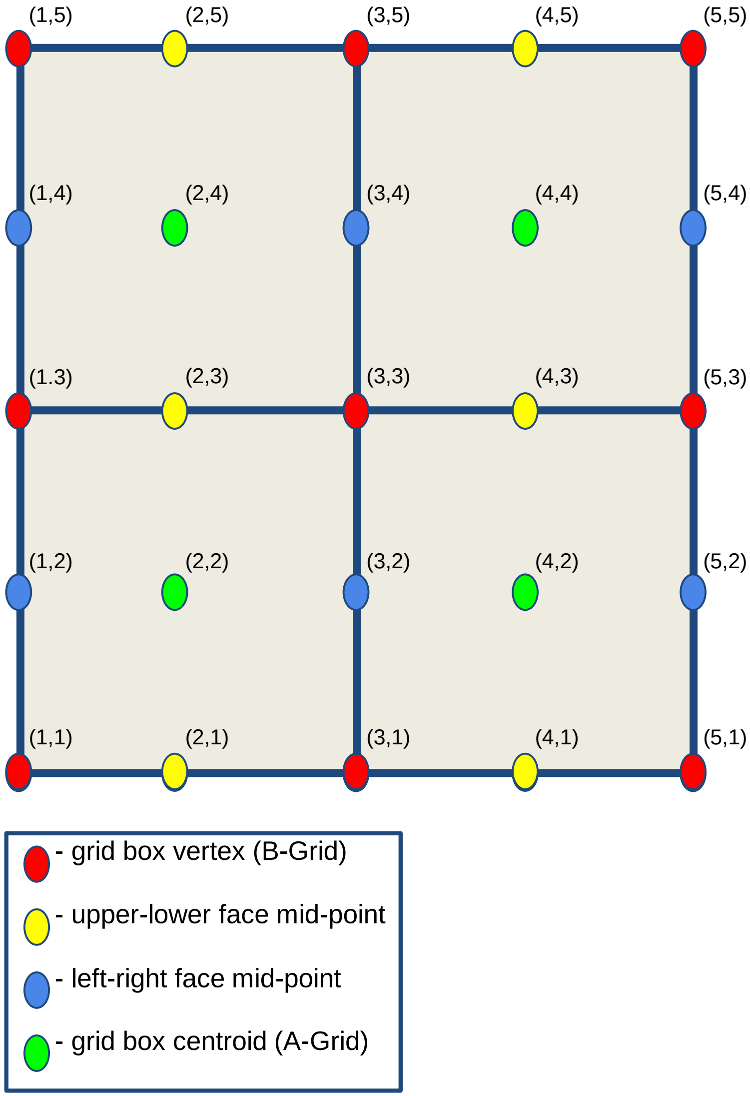
Mosaic Grid

- A standard for the description of grids used in earth system models.
- The standard is included in the Climate and Forecasting (CF) standard. (http://www.unidata.ucar.edu/software/libcf/)
- The standard will be supported in Ferret.
- The standard will support more complex grids --- Cubic Sphere grid, Nested grid.
- An entire coupled model application or dataset can be constructed as a hierarchical mosaic.

Mosaic Hierarchies



Where "G" is the tile grid file and "C" is the contact file.



Super Grid vs Model Grid

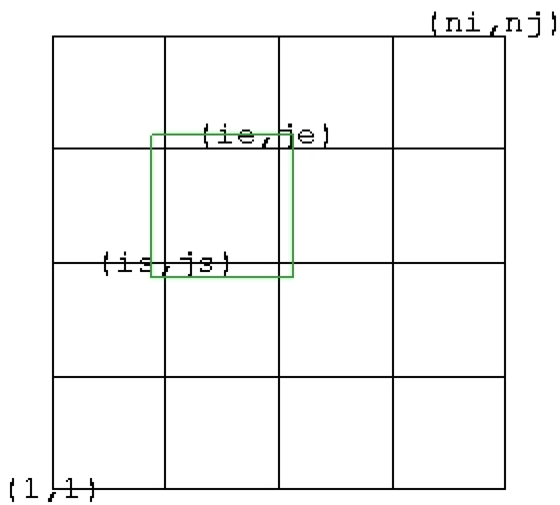
- The model grid is defined by the centroids only. Grid boxes are bounded by the vertices.
- The super grid is defined with the vertices, centroids, and face mid-points of the model grid.
- For a model grid size (ni, nj), the super grid size is (2*ni+1, 2*nj+1).
- Each super grid box consists of 9 points:
  - 4 vertices
  - 1 centroid
  - 4 face mid-points
- The graph on the left has 4 model grid boxes (2x2) and the super grid size is (5x5)
- The (i,j) index representation in the image corresponds to the points defined in the super grid
- The model grid is defined only by the centroids [(2,2), (4,2) etc.]

Communication kernels(mpp_mod)

- Provide uniform interface to MPI message passing across clusters.
- mpp_send, mpp_recv
- Mpp_sync, mpp_sync_self
- mpp_chksum
- Mpp_sum, mpp_min, mpp_max
- ….

Domain decomposition(Mpp_domain)

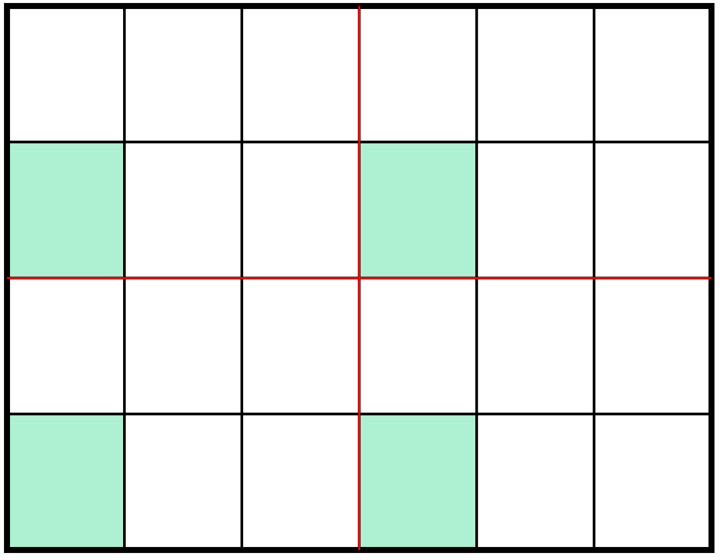
- decomposing the model domain into sub-domains that are distributed among processors.
- Layout(2): divisions in the decomposition.
- Global domain, compute domain and data domain.
- Provides method to fill the ghost cells.



Layout=(4,4) and the number of processor used is 16.

Input/Output (Mpp_io)

- Single-threaded I/O: a single PE acquires all the data and writes it out.
- Multi-threaded, single-fileset I/O: many PEs write to a single file.
- Multi-threaded, multi-fileset (distributed) I/O: many PEs write to independent files (requires post-processing).
- Define a IO domain with io_layout to improve the performance of high resolution model running on large processor count.
- Io_layout: divisions in the IO domain decomposition.



Layout is (6,4) and the program is running on 24 processors.

Io_layout is (2,2). 4 Processors write to 4 independent files.

FMS Nesting Support

- Done
  - FMS infrastructure supports two-way nesting (transfer data between coarse and fine grid, IO etc.) when a single nest region located within a single face of cubic sphere grid.
  - FMS coupler supports two-way nesting for single nest region
  - Tested in FV3 solo model and Hiram coupled model.

FMS Nesting Support

- Under development
  - FMS infrastructure to support multiple nesting region.
  - FMS infrastructure to support nest region cross the edge of cubic sphere grid face.
  - FMS infrastructure to support telescoping.
  - Extend FV3 to run multiple and telescoping nest model.

FMS Nesting Support

- Future Work
  - Extend FMS infrastructure to support moving nest.
  - Extend FMS infrastructure to support nest region cross the corner of cubic sphere grid.
  - Develop FV3 model to support moving nest and crossing corner (AOML Lead; GFDL support)

Thanks!