Check out GFDL's SHiELD real-time forecasts!

Github/FV3

Multiple same level and Telescoping nesting in GFDL's FV3

Joseph Mouallem[1,2], Rusty Benson[2], Lucas Harris[2]

[1]Cooperative Institute for Modeling the Earth System, Princeton University, Princeton, NJ

[2]Geophysical Fluid Dynamics Laboratory, NOAA, Princeton, NJ, United States

Motivation

- Running global models using uniform grids fine enough to fully resolve small scale features to accurately capture special weather events is still computationally expensive and sometimes impractical even with today's supercomputers.
- Grid nesting adds a refined grid over an area of interest to better resolve small scale flow features necessary to accurately predict special weather events such as severe storms and hurricanes.
- We present a new capability in GFDL's dynamical core FV3 that allows multiple and telescoping grid nesting. The following simulations were performed using GFDL's atmospheric model SHiELD which uses FV3 as its dynamical core.

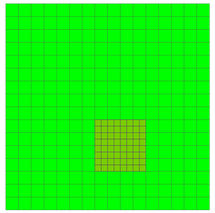
Nesting Methodology

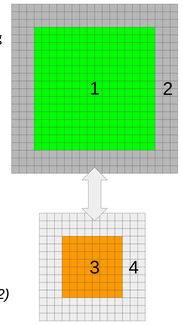
The parent <--> nest communication*:

- Update** nest halo (4) from parent compute domain (1)
- Advance simulation in time. Parents and nests run simultaneously on different sets of processors.
- Update** parent compute domain (1) from nest data (3) (Twoway update)

*Updates are performed level per level. No communication is performed among same level nests.

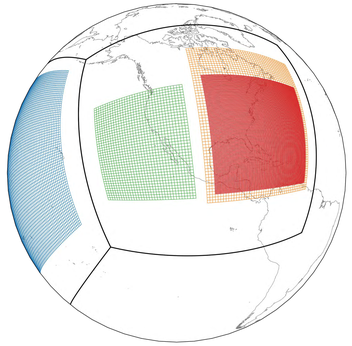
**Communication strictly occurs between a nest and its corresponding parent grid.



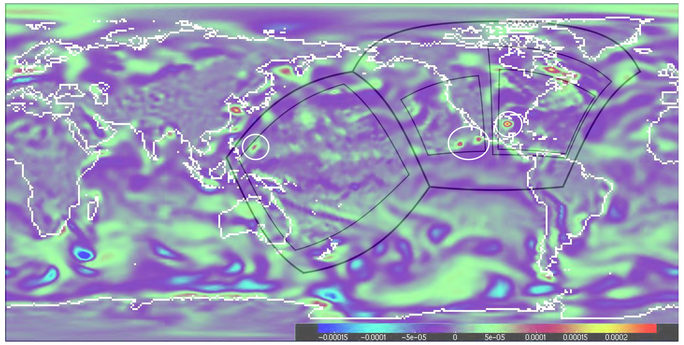


(L) Overlap region of the nest (rf=2) and its parent grid.
(R) Compute and halo domains of the parent and nested grids.

Results



Nested grid layout of the C48 global grid with three nests at the first level and one telescoping nest focused on hurricane Laura (number of cells in the depicted grids is reduced by a factor of four).

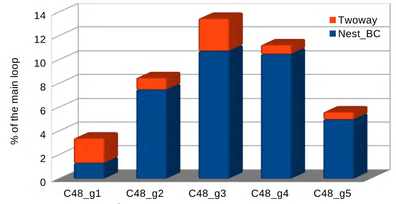


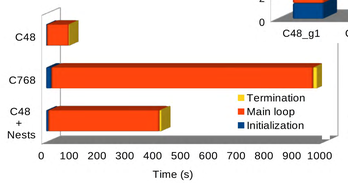
850mb vorticity of a SHiELD simulation of hurricane Laura's landfall of late August 2020 of a C48 global resolution and multiple same level and telescoping nests capturing various separate weather events.

Code Timing and Performance

Case	Description	Resolution	# of cores	Memory output files (GB)	Three days simulation time (s)
C48	Global uniform resolution: One grid: six tiles (48x48 per tile)	200km	6x6x6=**216**	0.04	84
C768	Global uniform resolution: One grid: six tiles (768x768 per tile)	13km	30x30x6=**5400**	16	975
C48 + Four Nests	Global uniform resolution: Grid1: six tiles (48x48 per tile) Nests: Grid2: one tile (145x145 Level1) Grid3: one tile (89x117 Level1) Grid4: one tile (69x81 Level1) Grid5: one tile (317x337 Level2)	200km 50km 50km 50km 12.5km	6x6x6=216 12x12=144 8x10=80 6x7=42 30x30=900 Total=**1382**	0.5	415

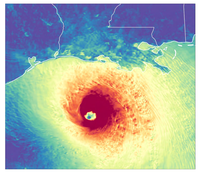
Time spent on the nest BC and fine to coarse twoway updates relative to the main loop time. Basically, this is the overall time spent on grid/grid communication.

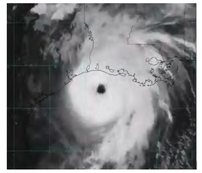




Time spent on the grids initializations, main loop (which consists of all grid comms and timestepping) and termination.

High Resolution Nesting





***(L)** High resolution snapshot of the velocity field magnitude of Hurricane Laura just before landfall taken from a telescoping setup (13-4.3-1.4km) **(R)** Satellite image.*

Conclusion

- Grid nesting has been shown to locally capture fine scale flow structures which are necessary to improve the accuracy of weather forecast models.
- Multiple same level and telescoping nesting in GFDL's FV3 is a very flexible framework allowing very high grid resolution over areas of interest to capture several and independent weather events around the globe.
- The multiple nesting algorithm yielding high resolution results over an area of interest is computationally cheaper than a global run of the same required resolution.
- Performance optimization and efficient code execution are case specific and potential algorithm improvements are matter of future investigation.

References

1. Lin, S.-J., & Rood, R. B. (1996). Multidimensional Flux-Form Semi-Lagrangian Transport Schemes. *Monthly Weather Review*, 124(9), 2046– 2070.
2. Lin, S.-J., 1997: A finite-volume integration method for computing pressure gradient force in general vertical coordinates. Quart. J. Roy. Meteor. Soc., 123, 1749–1762.
3. Lin, S. J. (2004). A "vertically Lagrangian" finite-volume dynamical core for global models. *Monthly Weather Review*, 132(10), 2293– 2307.
4. Harris, L. M., & Lin, S. (2013). A Two-Way Nested Global-Regional Dynamical Core on the Cubed-Sphere Grid, *Monthly Weather Review*, *141*(1), 283-306
5. Harris, L., Zhou, L., Lin, S.-J., Chen, J.-H., Chen, X., Gao, K., et al. (2020). GFDL SHiELD: A unified system for weather-to-seasonal prediction. *Journal of Advances in Modeling Earth Systems*, 12, e2020MS002223.