Multiple same level and telescoping nesting in GFDL's FV3

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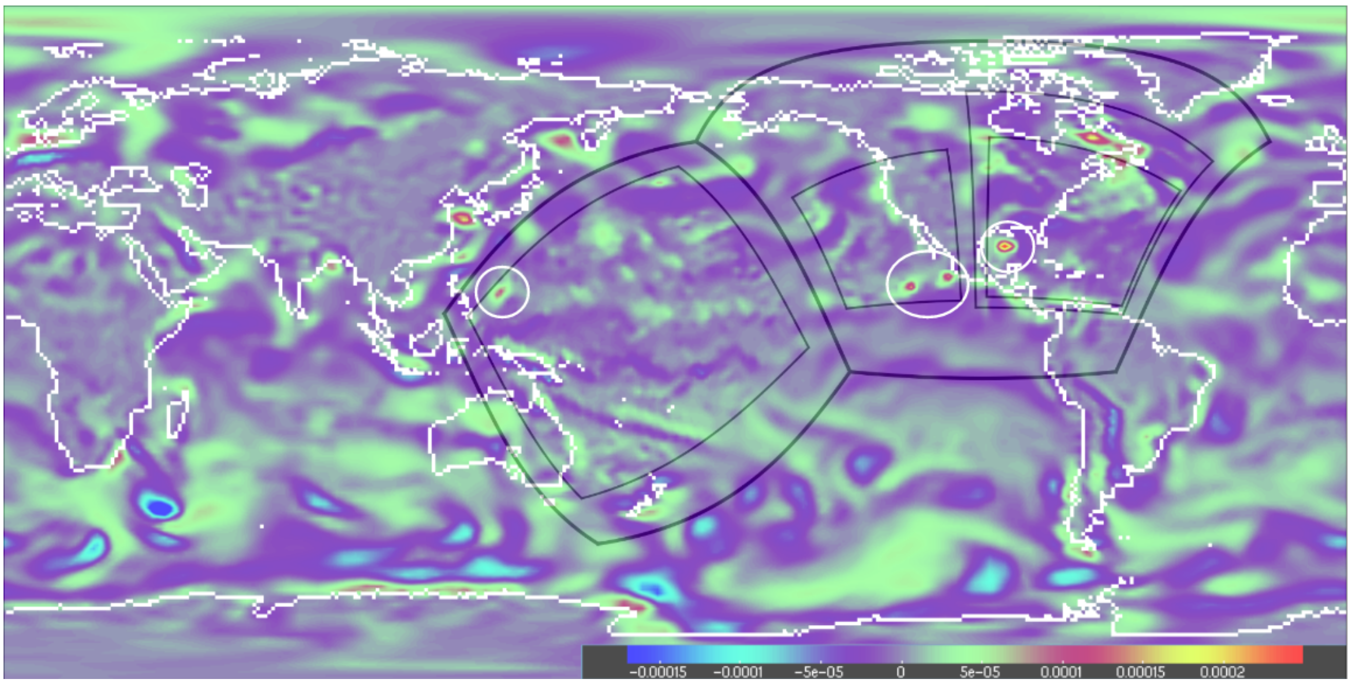

Figure 1. Top level 850mb vorticity of a SHiELD simulation of hurricane Laura's landfall of late August 2020 of a C48 global resolution and multiple same level and telescoping nests capturing various separate weather events, namely the initial stages of Typhoon Maysak and some intense weather activity in the gulf of Tehuantepec

Abstract

The current two-way, single nest capability in the FV3 dynamical core, used in weather and climate applications by a diverse group of institutions and organizations, is upgraded with the capability to employ multiple same-level nests as well as telescope, or embed, the various nests within each other. In particular, this capability has been much anticipated by the Unified Forecast System (UFS), from which the National Weather Service (NWS) draws to build the operational Global Forecast System (GFS) and various other applications of operational importance, as well as NASA's Mars Climate Modeling Center. 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. The latest developments in the dynamical core, FV3, developed at GFDL allow concurrent execution of multiple same level and telescoping nested grids. The two-way grid coupling has been proven to be a powerful tool to capture mesoscale flow structures thus improving the overall forecast accuracy. An overview of the nesting technique and code performance within the GFDL's atmosphere model SHiELD is presented.

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1 Introduction

GFDL's Finite-Volume Cubed-Sphere Dynamical Core, FV3[2–4], is used for weather and climate applications by several research laboratories such as the Atlantic Oceanographic and Meteorological Laboratory (AOML, NOAA), the Goddard Space Flight Center (GSFC, NASA), the Mars Climate Modeling Center (MCMC, NASA), the Environmental Modeling Center (EMC, NOAA) and more. FV3 is also is the dynamical core used in all climate and weather models at GFDL. Running high resolution global models on grids fine enough to capture special weather events such as hurricanes is still computationally expensive even with today's latest supercomputers. One of the techniques to overcome this issue is grid nesting. Grid nesting has been proven to be a powerful tool for resolving small scale flow features and thus improving the overall forecast ability of the models in question. In what follows, the nesting capability is presented within the atmosphere model SHiELD[1] (System for High-resolution prediction on Earth-to-Local Domains). Later on, the code performance is assessed for a low resolution global case with high resolution nests and a high resolution global case.

2 Nesting Methodology

FV3 uses a cubed-sphere grid that allows a uniform spatial coverage over the entire globe. Grid nesting allows adding an additional finer grid spanning over the area of interest. The added grid could be nested in one of the six tiles of the top level cubed sphere grid and it could also be nested in another nested grid. The latest setup is called telescoping nest. Each of the additional grids could be configured differently (time steps, physics parameterization) and runs concurrently on different sets of processors. The nesting algorithm could be roughly summarized in two steps: (a) The nests BC are spatially interpolated from the compute domain of its parent (b) The nest data is averaged and replaces the coarse data on the parent grid in the region where they overlap.

3 Results

We show, in this section, the code performance for the following cases: (a) Case C48: Global uniform top grid of 48x48 per tile yielding a resolution of 200km (b) Case C768: Global uniform top grid of 768x768 per tile yielding a resolution of 13km (c) Case C48 + nests: Similar to C48 with four additional nests spanning as in figure 1 with a telescoping nest of resolution 12.5 km capturing the landfall of hurricane Laura

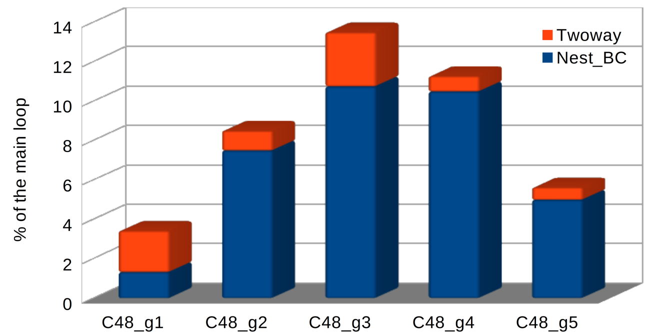

Figure 2. Percentage of the main loop time spent on the nest BC and fine to coarse twoway update. This is the overall time spent on the nests grid to grid communication

The global low resolution case C48 (200km) with four nests spanning over areas of interest as shown in figure 1 was shown to capture the evolution of the hurricane's landfall similar to a global C768 case (13km resolution) using much less computational resources: C48 with nests took 415s for a three days simulation on 1382 processors distributed among the five grids. C768 took 975s on 5400 processors for the same simulation time. If there is an interest in capturing localized, independent and separate weather events such as is figure1, using the multiple nest technology is found to be superior to a global case with the same high resolution in terms of computational resources without compromising the accuracy of the results. In addition, the communication between grids which is summarized in section2 takes roughly 13% of the total time of the main code loop for the processors layout considered in this study as shown in figure 2.

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