Improved Global Weather Prediction with GFDL's FV3 Dynamical Core

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Abstract

Global weather models are extremely computationally intensive, especially when run at high resolutions. With increasing HPC resources and the desire for better forecasts, the resolutions these models are demanded to run at is always increasing. The current U.S. National Weather Service operational Global Spectral Model (GSM) is a hydrostatic model and has reached its end-of-life. The field of global weather modeling has reached a point where resolutions are so high that non-hydrostatic, oron Global Prediction System (NGGPS) is being built to replace the GSM with a model that will improve forecasts and extend the predictability range out to 30 days, while keeping pace with changes in HPC resources over the next two decades. The Geophysical Fluid Dynamics Laboratory's Finite Volume dynamical core was chosen, through a two-year program of rigorous testing, to be part of this NGGPS.

Keywords -- numerical weather prediction, weather forecasting, modeling

I. INTRODUCTION

Global weather models are extremely computationally intensive, especially when run at high resolutions. With increasing HPC resources and the desire for better forecasts, these models are demanded to run at increasingly higher resolutions. supercomputers, but it also must scale well enough to perform on supercomputers 20 years from now. The The U.S. National Weather Service (NWS) operational Global Spectral Model (GSM), which currently runs at 13 km resolution, is a hydrostatic model and has reached its end-of-life. The field of global weather modeling has reached a point where resolutions are so high that non-hydrostatic, or cloud-resolving, models are required. The Next Generation Global Prediction System (NGGPS) is being built to replace the GSM with a model that will improve forecasts and extend the predictability range out to 30 days, while keeping pace with changes in HPC resources over the next two decades. The Geophysical Fluid Dynamics Laboratory's (GFDL) Finite Volume dynamical core (FV3) was chosen, through a two-year program of rigorous testing, to be part of this NGGPS.

II. NGGPS

The goal of the NGGPS project is to incorporate fully coupled atmosphere, ocean, ice, land, waves, and aerosol models using the NOAA Environmental Modeling System (NEMS) architecture while fully utilizing HPC capabilities. One of the biggest challenges is creating a dynamical core (dy-core) that is accurate from the large scales down to the scale of individual thunderstorms, and is inexpensive enough to run below 10 km resolution several times a day. The dy-core must be fast and efficient on today's

NGGPS should be a hybrid model that closes the gap between weather and climate models.

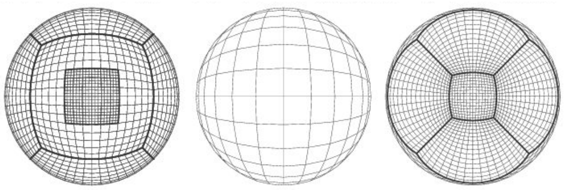

Fig 1. Nested grid (left), coarser region of stretched grid (center), refined region on stretched grid (right).

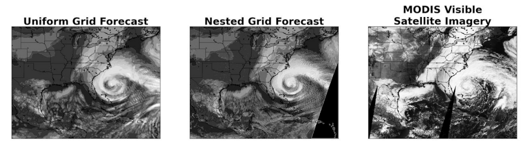

Fig 2. Nested grid forecast (top left), MODIS sateillite image from NASA Worldview (top right), uniform grid forecast (bottom) at 18 UTC October 27, 2012.

III. FV3 DYNAMICAL CORE

FV3 was designed to be computationally efficient and to have discretization guided by physical principles as much as possible. The fully finite-volume discretization has many benefits: the pressure gradient evaluation has errors an order of magnitude smaller than other schemes, the transport algorithm conserves mass and has no false vorticity generation, and the vertically-lagrangian discretization allows for efficient cloud-resolving applications (Lin 1997, 2004). FV3 uses a gnomonic cubed-sphere grid with grid-stretching and two-way nesting capabilities, as seen in Fig. 1, which allow for a computationally efficient way to focus in on an event or area of interest (Harris and Lin 2013).

During Phase II of the NGGPS dy-core testing, the candidate cores implemented the current Global Forecasting System (GFS) physics package to test several hindcast cases. Figure 2 shows a forecasts from FV3 with the GFS physics package (FVGFS) of Hurricane Sandy (2012) using a globally uniform grid at 13 km resolution. Figure 2 also shows the same FVGFS forecast using a stretched and nested grid configuration, where the highest resolution is ~3 km and the lowest resolution is ~30 km. The nested grid efficiency was an impressive 96.9% using 3072 processor cores (AVEC Benchmark Report Phase II), largely due to the ability to run shorter timesteps in the nested region and longer timesteps in the coarse-grid region. Competitors using mesh-refinement or grid-stretching techniques cannot take advantage of the different timesteps. A test case of a severe weather outbreak in Oklahoma (2013) will also be examined.

IV. SUMMARY

FV3 has no spatial or temporal scale restrictions making it an ideal choice for hybrid weather-climate applications. Much work still has to be done to develop the NGGPS, but choosing a dy-core was an important step forward. HPC plays a significant role in weather forecasting and will only increase in importance as forecasting becomes more complex in the future.

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