A Standalone Limited Area Capability for the Finite-Volume Cubed-Sphere Dynamic Core

Thomas L. Black[1], James A. Abeles[1,2], Benjamin T. Blake[1,2], Dusan Jovic[1,2], Eric Rogers[1], Ying Lin[1], Logan C. Dawson[1,2], Jacob R. Carley[1]

[1]*NCEP/EMC College Park, MD, U.S.*
[2]*IMSG, College Park, MD, U.S.*
Email: Tom.Black@noaa.gov

The Next Generation Global Prediction System (NGGPS) of the National Weather Service (NWS) is based on the Finite Volume Cubed-Sphere (FV3) dynamical core (Lin 2004; Putnam and Lin 2007). Models using this core have executed on domains that cover the entire globe. The responsibilities of the NWS include providing forecast guidance on the global scale as well as for more localized regions such as those within the United States and associated territories. Given that FV3 was originally built to run over the globe, a method was needed to focus the prediction over any desired limited area region. FV3 developers addressed this issue by adding a capability to insert a single nest domain within the global parent (Harris and Lin 2013). This configuration requires that the nest run concurrently with its parent to receive boundary updates at each parent timestep. However, if the specific goal is to forecast only for a limited region, then there is significant additional computational expense in also running a parent domain over the entire globe to provide boundary conditions for a nest with limited forecast length (i.e. ≤ 60 h). It is also impractical at present for convective-scale (≤ 3 km grid-spacing) data assimilation systems that feature analysis updates at a frequency of ≤ 1 hour, as they typically feature earlier data cut-offs than their global counterparts (Gustafsson et al. 2018). In order to avoid cost and data assimilation issues in global forecasts associated with a nest, a limited area or stand-alone regional (SAR) version of FV3 has been constructed. This version has no global parent and thus uses a completely isolated domain with boundary conditions pre-generated from an independent external forecast.

Within the theme of unifying global and regional NWP applications, the same version of the FV3 dynamic core that was enhanced for the standalone limited area capability is also planned for operational implementation in the Global Forecast System (GFS) at the National Centers for Environmental Prediction in 2019 (GFSv15). The uppermost section of source code lying over the forecast model is called the NOAA Environmental Modeling System (NEMS) layer. NEMS uses the Earth System Modeling Framework (Hill et al. 2004, Collins et al. 2005) and includes features providing the means to couple to other modeling systems provided by the National Unified Operational Prediction Capability (NUOPC) layer, which is a set of ESMF-based component templates and interoperability conventions. The forecast integration in the regional mode runs in precisely the same way as in the original global version and thus nearly all the modifications for a limited area forecast are directly or indirectly related to the handling of the domain's boundaries.

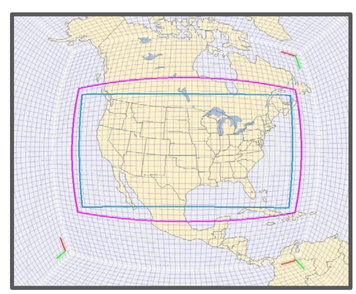

Figure 1. FV3-SAR and FV3-Nest computational domain (pink) and output grid (blue).

Currently EMC is running a regional FV3-SAR forecast with 3 km grid spacing over the CONUS along with a nested domain forecast with identical resolution and areal coverage (Fig. 1). Both forecasts run at 0000 UTC each day out to 60 hours using initial conditions from the 0000 UTC GFSv15 system. The FV3-SAR also leverages the 0000 UTC GFSv15 cycle for lateral boundary conditions, which are specified at a 3 hour interval. Both configurations currently utilize the GFSv15 physics suite for testing purposes.

Initial comparisons of forecast precipitation verification also demonstrate little practical difference in skill out to 60 forecast hours between the SAR and nested configurations (Fig. 2). This suggests that the lateral boundary conditions are being applied correctly and, at this early stage of development, less frequent boundary updates in the SAR domain appear to not have a detrimental impact on the resulting forecast. Finally, a compelling benefit of the SAR is that it requires significantly less computational resources to run the forecast. The global with a nest simulation runs 1.7x slower using the same number of nodes as the SAR (Fig. 3).

Work on applying data assimilation in this regional system has begun with the long-term goal of developing a convection-allowing, ensemble-based data assimilation and prediction system with at least an hourly-update cadence.

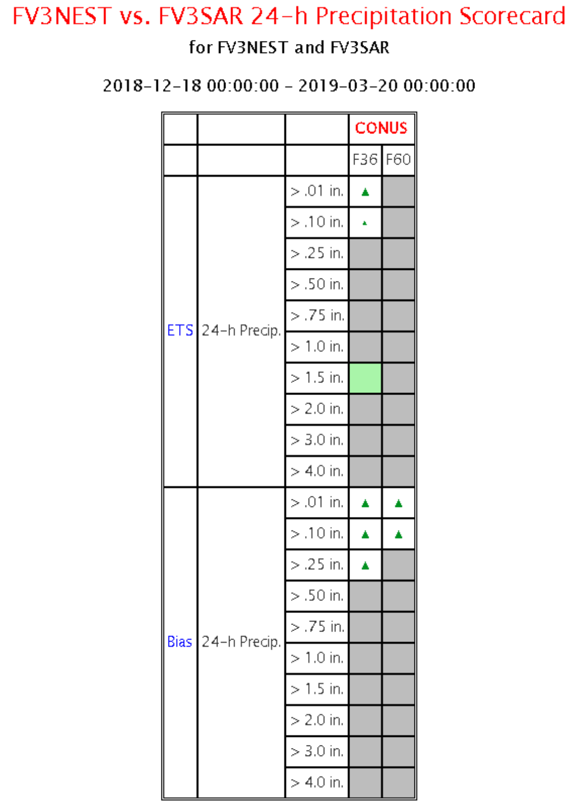

Figure 2. 3 km FV3-NEST vs. 3 km FV3-SAR precipitation scorecard for 24 hour accumulation periods ending at 36 and 60 forecast hours over the CONUS. Statistics cover the period from Dec. 18th, 2018 to March 20th, 2019. Large green (red) triangles indicate FV3-NEST is better (worse) at the 99.9% significance level, small green (red) triangles indicate FV3-NEST is better (worse) at the 99% significance level, green (red) shading indicates FV3-NEST is better (worse) at the 95% significance level.

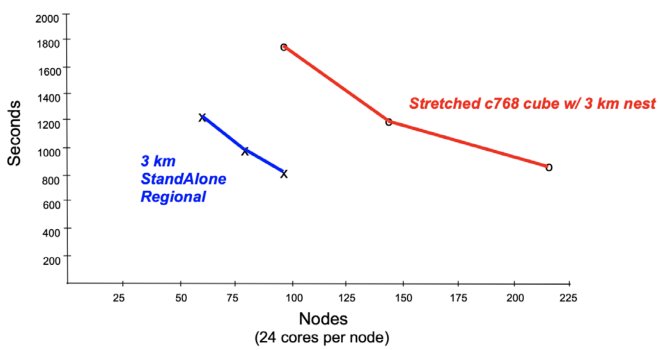

Figure 3. 3 km FV3-SAR (blue) vs. global FV3 with 3 km nest computational time as a function of node count (24 cores per node). No output/history files were written during model integration to minimize the influence of I/O contention.

References

Collins, N., and Coauthors, 2005: Design and implementation of components in the Earth System Modeling Framework. *Int. J. High Perform. Comput. Appl.*, **19**, 341–350.

Gustafsson N., and Coauthors, 2018: Survey of data assimilation methods for convective scale numerical weather prediction at operational centres. *Quart. J. Roy. Meteor. Soc., **144**, 1218-1256.*

Harris, L.M. and S. Lin, 2013: A Two-Way Nested Global-Regional Dynamical Core on the Cubed-Sphere Grid. *Mon. Wea. Rev.,* **141**, 283–306.

Hill, C., C. DeLuca, V. Balaji, M. Suarez, and A. da Silva, 2004: The architecture of the Earth System Modeling Framework. *IEEE Comput. Sci. Eng.*, **6**, 18–28.

Lin, S., 2004: A “Vertically Lagrangian” Finite-Volume Dynamical Core for Global Models. *Mon. Wea. Rev.*, **132**, 2293–2307.

Putman, W. M., and S.-J. Lin, 2007: Finite-volume transport on various cubed-sphere grids. *J. Comput. Phys.*, **227**, 55–78.