A DTC Proposal for the NGGPS Program Office

# Global Model Test Bed

## Year 3
## 1 July 2017 - 30 June 2018

The Global Model Test Bed's (GMTB) primary mission is to accelerate the research to operations (R2O) transition of broad community innovations in physical parameterizations and suites to NCEP operational models in order to improve numerical forecasts. The mission is multifaceted, and includes making innovations available to operations, as well as testing parameterization performance to inform decisions by the National Weather Service. This work started in 2015/2016 with the planning and initial implementation of a Common Community Physics Package (CCPP) and Interoperable Physics Driver (IPD). The following aspects are, or are anticipated to be, completed by June 2017:

1. Technical documentation for IPD v3 and 2016 GFS operational physical parameterizations;
2. Roadmap for CCPP implementation;
3. Documentation of IPD requirements;
4. Coding standards for IPD and CCPP;
5. IPD design;
6. Cap for the single column model to connect to the IPD;
7. Initial work toward cap for connecting the CCPP via the IPD to FV3;
8. Functional release of CCPP v0 to internal GMTB users and initial partners who contribute physics schemes, along with email help desk.

In addition, the GMTB designed and completed initial implementation of a hierarchical testbed, which has already been used to test the Grell-Freitas cumulus parameterization within the 2016 and 2017 GFS physics suite and inform EMC about its potential use in operations. By June 2018, the GMTB will have expanded physics options in the CCPP, and use its testbed framework to produce information to support evidence-driven decision making by EMC regarding choice of physics for its advanced suite.

## 2. Statement of Work

For year 3 (1 July 2017 - 30 June 2018), the DTC proposes to carry out work in the following four Focus Areas:

Focus Area 1: Code management and user support of a Common Community Physics Package and IPD

Focus Area 2: Update, expand, and support testbed scripts, workflow, and codes according to needs of the EMC and the NGGPS program

Focus Area 3: Testing and evaluation of high-priority physics parameterizations and suites

Focus Area 4: Program management support

### *Focus Area 1. Code management and user support of a Common Community Physics Package and IPD*

Both the weather and climate modeling communities recognize that innovations in physical parameterizations are the key to improving forecast models. To facilitate the R2O process for parameterizations in support of NGGPS, the GMTB proposes to support expanding the CCPP so that more physics are available to the FV3, and can be tested to quantify potential skill increases compared to operational or other proposed schemes and suites. Working with the developers, the GMTB will facilitate efficient and effective distributed development of parameterizations.

*i) FV3-ready CCPP*

In order to achieve the goal of enabling CCPP functionality using the FV3 dynamical core, the GMTB proposes to integrate its current CCPP driver capabilities within the IPDv4 as part of the initial CCPP software release. Through this activity, the flexibility within the IPDv4 can be extended to include run-time physics suite construction and flexible scheme ordering. A driving principle of the proposed work is to further reduce the time and effort required by physics scheme developers to add, remove, or modify physics by reducing the dependence on hard-coded physics suite drivers. The proposed work will be carried out to maintain backwards compatibility with the current way in which the GFS Physics suite is bundled. A software design for the proposed changes enabling the CCPP functionality will be submitted for approval.

ii) *Separation of GFS physics*

We propose to separate the parameterizations of the GFS physics suite for inclusion into the CCPP. Focus will be given to high-priority parameterizations for implementation in the advanced physics suite planned for GFS FY2019 operational implementation and beyond; priorities will be determined in collaboration with EMC and the EMC SIP Physics Working Group. Separation of obsolete parameterizations will not be performed.

The prioritized physics will be reconfigured to work independently of each other and to be fully compatible with the CCPP and its calls from the IPD. This requires writing caps for each individual scheme, and moving significant code that currently sits between physics schemes into the physics themselves or into the physics caps for each scheme. It is likely that initialization modules or functions for each scheme will also require development to enable the full interoperability. Implementation of this task will begin with version 0 of the FV3-GFS public release on VLab. The work will be performed in stages such that reproducibility with the aggregated GFS physics suite called from IPDv4 within FV3 is maintained. Note that the primary purpose of this activity is to separate the schemes and to enable compatibility with the IPD/CCPP, not necessarily to refactor code to meet the requirements put forth in a previous document meant for *new* schemes to be considered for inclusion into the CCPP.

This activity requires close communication with EMC physics developers to proceed quickly. The GMTB requests a point of contact (POC) inside EMC, or outside if most appropriate, who can answer technical questions as they arise and be available for technical web conferences at regular intervals. Availability of a relevant POC for conferences should be weekly while that particular scheme is being rolled into the interoperable CCPP.

*iii) Code management and governance for CCPP*

Maintaining an effective code management structure is critical for an effective community-based R2O process. Maintenance of the code repository, introduction of new regression and unit tests, and ensuring the repository is properly configured comprise code management activities. The initial CCPP repository was established during year 2 under the NCAR space on GitHub and initial code management and governance plans have been completed. The plans include coding standards, version control protocols for checking new physics development into the CCPP repository, and regression testing. The code management plan and associated governance will evolve to meet NGGPS's evolving needs and community engagement. Finally, work will be undertaken to ensure the community is engaging the repository correctly.

The proposed governance supports the entire physics R2O pipeline, including assessing and identifying physics with potential for future development, physics advancement to the supported CCPP based on testing results, and readiness for pre-operations. It is built upon information that flows from the community, which includes EMC, the EMC Strategic Implementation Plan (SIP) Physics Working Group, and other contributors to be determined. The GMTB solicits and synthesizes inputs and then recommends to the NGGPS Program Office and EMC regarding the position of a particular physics within the various phases of the R2O pipeline. The GMTB, EMC and NGGPS Program Office then iterate to agree on priorities, and perform a review that occurs at some regular, but infrequent, interval.

*iv) Community support*

Providing support to both the broad community and key developers is critical to the success of any community package. Key aspects to providing community support are detailed documentation for the package, help desk support, and tutorials. The GMTB will inform developers on technical requirements for CCPP codes, which include documentation and proper repository engagement. The GMTB will also update the CCPP Users Page, which serves as an access point for both the CCPP documentation and periodic releases of the CCPP.

Deliverables:

- GFS physics separated to meet CCPP interoperability requirements
- Established governance for the CCPP by GMTB making recommendations of which physics to test/include, and interfacing with NGGPS PO and EMC to obtain approval.
- Software design for changes enabling the CCPP; CCPP release with separated 2017 operational GFS physics and FV3 compatibility
- Community support through an email help desk and web pages with documentation for including physics in the CCPP, creating caps to other dynamical cores, and using the CCPP repository.

***Focus Area 2: Updated and expanded testbed scripts, workflow, and codes according to needs of EMC and the NGGPS program***

While the physics testbed has already proven its usefulness during the initial performance periods, we propose to update and improve the physics testbed tools to keep pace with operational changes and community input and to provide an integrated and easier-to-use interface.

*i) Workflow enhancements, including portability*

During the first two years of the GMTB project, the capability was established to run the GSM, post-processor, verification, and plotting tools through a workflow management system on Theia, first as a cold-start only, then using cycled data assimilation. This capability will be updated for the transition to FV3 through close collaboration with the appropriate groups at EMC. In addition, collaboration with EMC for developing requirements for the NCEP Unified Scientific Workflows for Research, Development, and Operations is anticipated.

*ii) Physics testbed integration*

Capability for testing inside the GMTB, and for community testing of physics innovations, is supported by the GMTB physics testbed. The physics testbed tiers have been implemented relatively independently so far, and an effort will be made to integrate them. An attractive, user-friendly website for testbed users will be established. This website will be used to display GMTB-assembled documentation on the individual tiers, and overarching documentation that ties the tiers together, such as an overview of current capabilities and suggestions on how to conduct testing of a physics scheme or suite.

*iii) Expanded verification and diagnostics in physics testbed*

A key lesson learned from work completed in previous performance periods was that the traditional forecast verification metrics are most useful for later stages of physics testing, ideally *after* a scheme has been tuned to work within a suite. Given GMTB's focus on relatively earlier stages of physics testing, likely before much tuning has been performed on a scheme in the context of a new suite, our testbed should be positioned to provide evidence of how new schemes represent specific physical phenomena. While both diagnostics and verification metrics will be created by GMTB for the lower tiers of testing to create a baseline (such as cold starts at medium resolution), forecast verification metrics are progressively more relevant as the parameterization advances to higher tiers of testing. Toward this goal, we have identified the following improvements in diagnostics. From literature review and collaboration with experts within the community, a list of specific diagnostics useful for determining how physical phenomena are being represented will be compiled, documented, and shared via a website. Such a list will form the basis for determining any added value from using different parameterizations and will guide future testing practices. For example, from our initial testing of the Grell-Freitas scheme, we identified convective heating rate and the partition of convective versus grid-scale precipitation as key indicators of convective parameterization behavior. For PBL schemes, the shape of vertical subgrid-scale fluxes in the PBL, PBL height and its evolution, low cloud fraction, and frequency distribution of precipitation rates (focusing on lower bins) are important indicators of scheme quality. It has also been suggested to add station-based soundings in skew-T log-P form from global model output to diagnose surface and boundary layer properties. The addition of SCM cases based on the BOMEX, RICO, and DYCOMS field campaigns will also help to quantify differences in PBL and shallow convection schemes. GMTB will initiate the list and provide an avenue for community input, including suggested datasets for SCM testing.

Part of this effort will involve closer collaboration with DTC's MET verification team, as capabilities from the maturing MET+ unified verification system will be adopted. With DA cycling included in the testbed, one example of this collaboration is the use of binary diagnostic files containing the innovation (i.e., observation - background) for each of the assimilated conventional and radiance observations. This information is used by physics developers to quantify model biases, and is a part of the MET system.

Additionally, new datasets can be used to provide evidence of scheme improvement. Currently EMC uses climatology-based analyses for their cloud and radiative flux evaluation. They suggested enhanced verification using ground-based and satellite observations. The GMTB will address this by providing observation data sets, for example Surface Radiation Budget Network (SURFRAD) data, as well as necessary scripts to diagnose and verify cloud and radiation fields (e.g., cloud fraction and radiative fluxes).

Deliverables:

- Mature and portable workflow, including FV3 capability, reflecting the EMC workflow capabilities necessary for testing, but adapted for broader use. GMTB will contribute to advancing the workflow development as deemed appropriate through discussions with EMC.
- Enhanced workflow with new capabilities from MET and MET+, including information from GSI diagnostic files. New datasets for testing, including SURFRAD, coinciding with input data sets for running the models added to the workflow, for GMTB test cases.
- Website with links to workflow repository, testing documentation, and information about the purpose of testbed tiers. Inventory of diagnostic quantities useful for gauging improvement in representation of specific physical process and software to analyze the supported diagnostics. Expanded number and breadth of SCM cases.

***Focus Area 3: Testing and evaluation of high priority physics parameterizations and suites***

A primary function of GMTB is to conduct testing and evaluation of new capabilities for potential transition to operations. GMTB will partner with developers to test the parameterizations in various tiers of the testbed, ranging from SCM to global forecasts with cycled data assimilation. Tests will follow the paradigm of the CCPP Governance, with progressively more complex testing for schemes that show promise for improving operations. The selection of which schemes to test will follow an open call and period of engagement with funded developers, and be determined in consultation with EMC and the NGGPS Program Office, taking into account input provided by the EMC SIP Physics Working Group. With support from GMTB, physics developers will take the primary responsibility for connecting the physics to the model.

Ultimately, all SCM tests will be conducted in the CCPP framework. However, until the CCPP is fully functional for the addition of parameterizations, some tests may be conducted in the current GFS_driver.f90 framework. Similarly, all FV3 tests will ultimately be conducted in the CCPP framework, but until the FV3-ready CCPP is available, tests will be conducted in the GFS_driver.f90 framework. As stated above, the tests undertaken by the GMTB will be routinely reviewed and approved by the NGGPS Program Office. Results from all tests conducted will be summarized in reports and posted on the DTC website. Reports will include recommendations regarding physics readiness for advancing in the testing hierarchy and/or incorporation to the supported CCPP.

Deliverables:

- Recommendations of which schemes will be tested through open call and engagement with funded developers.

- Reports with evaluation of tests conducted by GMTB using one or more of the hierarchical testing tiers, with recommendations on physics readiness for advancing in the testing hierarchy and possible incorporation in supported CCPP.

***Focus Area 4: Program Management Support***

The DTC Director's Office will be responsible for the planning, coordination, management, and reporting of activities funded by the NGGPS Program Office. This work includes the development of a detailed work plan and budgets. The DTC Director's Office will be responsible for communication and coordination with EMC and other community partners to ensure smooth execution of the GMTB SOW. For example, the transition of the GFS physics suite into the Common Community Physics Package will require a lot of coordination with physics developers at EMC.

Deliverables:

- Quarterly (joint) and monthly (NCAR and GSD separately) reports on overall progress of NGGPS-funded activities and monthly coordination meetings to discuss progress and impediments