**A DTC Proposal for the NGGPS Program Office**

**Global Model Test Bed**

**Year 4**

**1 July 2018 – 30 June 2019**

## Background

The GMTB's primary mission is to accelerate the research to operations (R2O) transition of broad community innovations in physical parameterizations and suites to National Centers for Environmental Prediction (NCEP) operational models in order to improve numerical forecasts. The mission is multifaceted, and includes supporting to the community an evolving library of physical parameterizations (the Common Community Physics Package – CCPP) that can be used with NCEP's Finite-Volume Cubed-Sphere (FV3)-based modeling system, as well as other modeling systems, maintaining a hierarchical testbed for DTC staff and community collaborators to assess physics at various complexity levels, and conducting testing and evaluation (T&E).

Prior to the period of performance for this SOW, the GMTB will have publicly released two versions of the CCPP containing the parameterizations of the current operational GFS physics suite with connections to the GMTB single-column model (SCM; CCPP v1) and FV3 (CCPP v2). With these releases, CCPP will be ready for use by the community at large, including recipients of the NGGPS federal funding opportunities. Work for the base period of this SOW will build on this foundation with the addition of new parameterizations to the CCPP and generalization of its framework, striding toward establishing the CCPP as the framework for physics development for all applications that use the Unified Forecast System (UFS), including Convective-Allowing Models (CAM), hurricane models, global weather (GFS), global ensemble (GEFS) and subseasonal to seasonal (S2S).

The GMTB has already put in place a hierarchical test harness for physics development, composed of the SCM and a workflow that allows running the FV3GFS in user-selected resolutions, in cold-start mode or with cycled data assimilation. These tools were successfully used by scientists from GSD and the NOAA Center for Atmospheric Science (NCAS) to evaluate and improve one of the candidates for the FV3GFS advanced physics suite. For the base period of this SOW, the SCM library of cases will be expanded and the global workflow will be enhanced with the Community Research and Operations Workflow (CROW), additional diagnostics and verification metrics.

The new capabilities listed above, additional parameterizations in the CCPP, and new elements in the test harness, will be used during the base period of this SOW to test innovations for the Fiscal Year 2020 (FY20) implementation.

## Scope

### 1. New and updated parameterizations in the CCPP

It is important to add to the CCPP the candidate physics for the FY20 implementation of the FV3GFS. This work involves a collaboration between physics developers and GMTB, with the roles and responsibilities detailed in Tables 1 and 2 . The scope of the work is to produce scientific and technical documentation, with the latter being used for the auto-generation of physics *caps* needed to connect the schemes to the dynamic core (dycore). Some of the schemes in the candidate FY20 suite may already be in the current CCPP, in which case code updates and consolidation will be done to make them easier to follow, more efficient, and use a smaller memory footprint (see Table 3). Resources permitting, GMTB staff will consult with the NGGPS Program Office (PO) regarding additional capabilities that could be added, such as physics for the hurricane problem. A distinction should be made between parameterizations that are CCPP-compliant from a technical standpoint and parameterizations that are accepted onto the supported CCPP. Supported schemes include those grandfathered in (GFS FY17 suite), as well as those that have passed the criteria to be specified as part of the CCPP Governance (see activity

2 below). The work outlined here does not involve testing and evaluation directed at forecast metrics. Rather, the testing is restricted to the technical work of making the parameterizations CCPP compliant.

**Table 1. Schemes to be made CCPP-compliant by GMTB staff.**

| # | Type | Scheme | Collaborator |
|---|---|---|---|
| 1 | Convection | Chikira-Sugiyama | Moorthi |
| 2 | Planetary Boundary Layer (PBL) | Simplified Higher Order Closure (SHOC) | Moorthi / Belochitski |
| 3 | Microphysics | Geophysical Fluid Dynamics Laboratory (GFDL) | GFDL |
| 4 | Microphysics | Morrison-Gettleman | Moorthi |
| 5 | Gravity wave drag (GWD) | Unified GWD | Alpert |
| 6 | Ozone and H20 | New | Moorthi |

**Table 2. Schemes to be made CCPP-compliant by third parties with support of GMTB staff.**

| # | Type | Scheme | Lead |
|---|---|---|---|
| 1 | Convection | Grell-Freitas | Grell and Olson |
| 2 | PBL | Mellor–Yamada–Nakanishi–Niino (MYNN) | Grell and Olson |
| 3 | Surface Layer | MYNN | Grell and Olson |
| 4 | Microphysics | Thompson-Eidhammer | Grell and Olson |
| 5 | GWD | Rapid Refresh (RAP) / High Resolution Rapid Refresh (HRRR) | Grell and Olson |
| 6 | Radiation | Radiative Transfer Equation (RTE) / Rapid Radiative Transfer Model for GCMs Parallel (RRTMGP) | Pincus |
| 7 | Land Surface Model (LSM) | Rapid Update Cycle | Grell and Olson |

**Table 3. Existing schemes in CCPP that are candidates for updates**

| # | Type | Scheme | Lead |
|---|---|---|---|
| 1 | Convection | Scale Aware-Arakawa-Schubert (SA-SAS) | Han |
| 2 | PBL | Hybrid-eddy-diffusivity mass-flux (EDMF) | Han |
| 3 | Radiation | RRTMG | Hou |
| 4 | Land Surface | Noah | Wei |

**2. Enhancements to the CCPP framework and governance**

The CCPP framework will be further generalized to more broadly address the range of candidate parameterizations. Enhancements will include computational performance enhancements, the ability to convert units in case the parameterization units differ from that for the dycore (e.g., meter versus millimeter), and the ability to calculate missing variables (e.g., relative humidity from temperature and dewpoint). In addition, some code of the CCPP framework will be refactored for clarity and performance improvement. The GMTB will manage the code repositories and contributions. The CCPP Governance will be expanded with the establishment of a Change Control Board (CCB), whose scope, terms of reference and membership need to be clearly defined. The Environmental Modeling Center (EMC) and the NGGPS Physics Working Group will gather input from a number of sources, e.g., EMC, the NGGPS PO, the UFS Steering Committee (SC), the GMTB, and the community for defining the criteria and reviewing test results for inclusion in the supported CCPP, and provide the CCB with a recommendation. Criteria for inclusion in the CCPP are yet to be established, but could include scientific aspects (such as

merit as a mature development through peer-reviewed literature or use in NWP applications, sufficient differences from other schemes already in the CCPP, potential for advancement of the scientific/forecast mission, and evaluation through hierarchical testing) as well as technical aspects (meeting CCPP requirements, meeting code and documentation standards, passing the regression tests, and undergoing evaluation of computational resources). GMTB staff will participate in the DTC Model Test Plans and Metrics workshop planned for July 2018 to gather input to the process of accepting new contributions onto the CCPP. GMTB staff will remain in contact with the NCAR Community Physics Framework development in order to seek a common path forward for currently identified partners.

**3. Augmented hierarchical test platform**

The hierarchical testbed will be maintained and augmented to make it most relevant for physics developers and National Weather Service (NWS) decision makers. New cases (e.g. BOMEX, DYCOMS, RICO, CASES), including their associated observational and Large-Eddy Simulation (LES) datasets when available, will be added to the SCM to cover additional weather regimes. In addition to GMTB standing up new cases, GMTB staff will encourage the community to stand up new cases through support from the DTC Visitor Program. Cases that act as parameterization simulators will be highly considered, as they allow a single type of scheme (e.g., deep convection) to evolve while all other schemes are forced, and therefore enable controlled investigation of the merits of one scheme over another (e.g., one deep convection parameterization versus another). The global workflow will be enhanced to keep pace with EMC practices, including use of the Community Research and Operations Workflow (CROW) and Model Evaluation Tools (MET)+ as they become available. Additional diagnostics and verification metrics will be added, including those that provide process-oriented information. These enhancements may include use of additional verification datasets, such as satellite-derived cloud and energy budget information, as well as additional tools, such as output of tendencies from the parameterizations and an expansion of the use of data assimilation radiance forward operators for pairing observations and forecasts in regions void of conventional observations. Diagnostic tools originating from other NGGPS-funded projects will be given special consideration. Workflow enhancements will be made available to EMC for inclusion in CROW. Additionally, in order to contribute to a more portable and flexible FV3GFS, GMTB will make code changes necessary to build and run EMC's FV3GFS v1 public release on Cheyenne, and make them available to EMC through EMC's Virtual Lab (Vlab) repository.

**4. CCPP and hierarchical testbed community support**

GMTB will provide user and developer support for the most recent version of the CCPP and the hierarchical test harness. Prioritization for efforts to be supported will be provided by the NGGPS PO. Support will include help with running the SCM, conducting verification and diagnostics, and contributing physics innovations, whether enhancements to existing schemes or new schemes altogether. When contributing new schemes, developers will be prompted to also contribute scientific and technical documentation, with the latter being used for the auto-generation of *physics caps*. It is understood that basic support for running FV3-based modeling system will be supplied by other groups (EMC, other task areas in the DTC, etc.). GMTB support mechanisms will include an informative website with the supported capabilities, a CCPP Version 3 public release containing the FY20 FV3GFS advanced physics suite, a User's' Guide on running and contributing to the CCPP, an email help desk, an in-person tutorial, and information about how to conduct tests with experimental code. A tutorial will be held at NCWCP, and will target physics developers.

**5. Testing and evaluation of physics innovations**

Significant effort will be devoted during this PoP to adding the candidate physical parameterizations for the FY20 operational implementation. The T&E activities will focus on leading the evaluation of two innovations geared toward the FY20 implementation. T&E activities will be dependent on computational resources.

**6. 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.

If NWS priorities change before the end of the PoP, the efforts may be shifted to the higher priority requirements.

**7) Milestones**

| # | Milestone/Subtask | Start Date | Stop Date | Deliverable |
|---|---|---|---|---|
| **1.0** | **New and updated parameterizations in the CCPP** | | | |
| **1.1** | Add or update parameterizations listed in Tables 1 and 3 to CCPP | Jul 2018 | Sep 2018 | CCPP repository updated with parameterizations in Tables 1 and 3. Report on computational resources used by new schemes, as well as reproducibility of results for schemes already in FV3GFS. |
| **1.2** | Support the addition of parameterizations listed in Table 2 to CCPP | Jul 2018 | Dec 2018 | CCPP repository updated with parameterizations in Table 2. Report on computational resources used by new schemes, as well as reproducibility of results for schemes already in FV3GFS. |

| # | Milestone/Subtask | Start Date | Stop Date | Deliverable |
|---|---|---|---|---|
| **2.0** | **Enhancements to the CCPP framework and governance** | | | |
| **2.1** | Generalization and performance improvement of the CCPP framework | Oct 2018 | Jun 2019 | CCPP repository updated with generalized code to accommodate needs of new parameterizations with priority given to computational performance improvements, unit conversions and computation of derived variables. |
| **2.2** | Participation in the SIP/UFS Test Plans and Metrics workshop | Jul 2018 | Aug 2018 | Attendance and contribution to the SIP/UFS Test Plans and Metrics workshop |
| **2.3** | Establishment of community-inclusive CCPP governance, controlled by the CCB | Jul 2018 | Sep 2018 | CCPP Governance document |
| **2.4** | Manage CCPP code repository and contributions | Jul 2018 | Jun 2019 | Information about access requests and contributions included in GMTB monthly report |

| # | Milestone/Subtask | Start Date | Stop Date | Deliverable |
|---|---|---|---|---|
| **3.0** | **Augmented hierarchical test platform** | | | |
| **3.1** | Additional SCM cases | Jul 2018 | Jun 2019 | Additional SCM cases published in GMTB website |
| **3.2** | Updated and enhanced global workflow | Jul 2018 | Jun 2019 | Global workflow enhanced and updated to use CROW available and described in DTC website |
| **3.3** | Additional diagnostics and verification capabilities | Jul 2018 | Mar 2019 | Additional diagnostics and verification capabilities available and described in DTC website |
| **3.4** | Porting of the forecast model component of FV3GFS to the NCAR Cheyenne HPC platform | Jul 2018 | Sep 2018 | Code in the FV3GFS repository and a document directed at EMC and the NGGPS PO detailing how to run on Cheyenne. |

| # | Milestone/Subtask | Start Date | Stop Date | Deliverable |
|---|---|---|---|---|
| **4.0** | **CCPP and hierarchical testbed community support** | | | |
| **4.1** | CCPP public release containing the FY20 FV3GFS advanced physics suite | Oct 2018 | Feb 2019 | CCPP public release |
| **4.2** | Community support for CCPP and hierarchical testbed | Jul 2018 | Jun 2019 | Updates to website describing supported capabilities, governance, the CCPP Users' Guide, ongoing email help desk |
| **4.3** | CCPP and hierarchical testbed tutorial | Jan 2019 | Mar 2019 | CCPP and hierarchical testbed tutorial |

| # | Milestone/Subtask | Start Date | Stop Date | Deliverable |
|---|---|---|---|---|
| **5.0** | **Testing and evaluation of physics innovations** | | | |
| **5.1** | Test and evaluate two candidate innovations for FY20 operational implementation | Jan 2019 | June 2019 | Report of T&E results |

| # | Milestone/Subtask | Start Date | Stop Date | Deliverable |
|---|---|---|---|---|
| **6.0** | **Program management support** | | | |
| | Planning, coordination, management, and reporting | Jul 2018 | | Monthly reporting and coordination meeting to discuss progress and impediments<br>Monthly NCAR written report |