A DTC Proposal for the NGGPS Program Office

Global Model Test Bed

1 July 2015 – 30 June 2016

1. Introduction

The overarching objective for the NOAA R2O Initiative is the design, development, and implementation of the Next-Generation Global Prediction System (NGGPS), with a goal to provide enhanced forecasting capability from a few hours to 30 days. The NGGPS is a full earth-system model, with components including atmosphere, ocean, wave, sea ice, land surface, aerosol, and space weather. All the modeling components will be connected through the NOAA Environmental Modeling System (NEMS) framework, compliant with the protocols of the Earth System Modeling Framework (ESMF). Initial NGGPS development is a five-year community effort. All its components, including atmosphere (dynamic core, physics, and aerosols), ocean, ice, waves, land, and data assimilation, are expected to be community codes. Once the NGGPS is implemented, NCEP will migrate from its current operational modeling suite to an integrated and coupled system, with annual (as needed) upgrades to existing components. High-resolution nesting will be developed to support convective-scale forecasting. The software architecture will be upgraded periodically as appropriate to take advantage of the next generation HPC (high performance computing). The Environmental Modeling Center (EMC) will upgrade its current infrastructure to support community participation in the NGGPS development. To solicit the participation of the science community, NOAA distributed an external announcement of opportunity (AO), with $3.9 M awarded to university Principal Investigators (PIs). In addition, NOAA distributed internal AOs targeted at NOAA and Navy laboratories with a total award of $2.4M. This funding will strongly encourage community participation in the development of NGGPS. To ensure these funded community efforts contribute directly to the development and implementation of NGGPS, an effective R2O process is needed. In particular, the research community needs an infrastructure that will enable them to efficiently and effectively use the NGGPS modeling system and/or its component models for research, which would, in turn, contribute to further improvement of NGGPS and its component models.

The Developmental Testbed Center (DTC) was established in 2003 with the objective to facilitate R2O in numerical weather prediction (NWP). Over the past 12 years, the DTC has supported several NCEP operational systems to the community, including HWRF, GSI/EnKF, WRF/NMME, NEMS/NMMB, and UPP. These community-support efforts include documentation, code management, tutorials (online and resident), and helpdesk support for users. The DTC has also provided support to HWRF developers, funded by the HFIP program, to ensure that these development efforts contribute directly to the improvement of the HWRF model. New capabilities in these software packages have also been introduced through the DTC Visitor Program. Through independent testing and evaluation, the DTC has evaluated numerous NWP innovations and provided the test results to operational centers (e.g., EMC and Air Force) for them to make decisions on further testing and operational implementation.

To facilitate the R2O process for the continued development of NGGPS, the DTC proposes over a multi-year effort to engage the global modeling community by working with the developers to establish the infrastructure necessary to efficiently and effectively support distributed development and transition the most promising innovations into operations. The proposed Global Model Test Bed (GMTB) to be developed over the first two years, initially for the model itself without data assimilation, will serve two main objectives: (1) developmental testing of new functionality of NGGPS components, and (2) fostering community involvement in ongoing development of operational modeling systems. To fulfill these objectives, the DTC will contribute to selected aspects of: (i) community code management; and (ii) infrastructure for the community to interact with the NGGPS code system. In addition, the DTC will (iii) support the NGGPS code system and preliminary global model capabilities to external developers, and (iv) facilitate and perform testing and evaluation of innovations to operational system from external community. The DTC will build off HIWPP global model verification capabilities for these efforts where appropriate. The DTC will also carry out selected verification activities with developers as an exercise toward future NGGPS experiments. A test plan will be developed for each verification activity and conducted upon approval of the NGGPS Program Office. Additional efforts can be included in the future as appropriate based on the needs of the NGGPS Program.

2. Statement of Work

For the first year, from 1 July 2015 through 30 June 2016, the DTC proposes to carry out the following five tasks:

Task 1: Code Management, Testing, and User Support for a Common Community Physics Package

Task 2: Code Management and User Support for Interoperable Physics Driver

Task 3. Integration, Testing and Improvement of a Sea Ice Model for NGGPS

Task 4: Program Management Support

Task 1. Code Management, Testing, and User Support for a Common Community Physics Package

Parameterization of physical processes is a very important component of a NWP model. The development of physical parameterizations (PP) is a critical part of continued global model improvement. Increased forecast skill can be expected as more physical processes are accounted for and with the increased sophistication appropriate for the model resolution and application. As part of the NGGPS Implementation Plan, the NGGPS Physics Team developed a draft Physical Parameterization Development Plan. This plan recognizes that, although the current NCEP GFS model has a strong suite of PPs, several areas of the current GFS physics needs further improvement. Areas of improvement include: (1) scale-aware convective and boundary layer formulations, (2) aerosol interactions with microphysics and radiation, (3) increased sophistication in microphysics, (4) interactions between all physical processes (e.g., radiation, clouds, microphysics and aerosols), (5) a physically-based framework for stochastics in ensemble prediction, and (6) advanced code structures to support model applications over a wide range of temporal and spatial scales: hourly weather to climate, and with horizontal grid resolution varying from 1 to 100 km. To support the development of PPs in different areas, the Physical Parameterization Development Plan recommended that a Scientific Working Group (SWG) be established for each major physical process area, including: (i) convective and boundary layer, (ii) cloud microphysics, (iii) aerosols, ozone and other required chemistry, (iv) radiation, (v) gravity wave and large-scale orographic (and non-orographic) drag, and (vi) earth-system surface fluxes and state.

Given the NGGPS's goal of providing improved accuracy for forecasting from a few hours to a month for resolutions ranging from 1 to 100 km, it is anticipated that options within a suite of physical parameterizations will likely be necessary to meet all the needs of the different NGGPS forecast applications. For example, options for PPs for short-range high-resolution convection prediction may differ from those for month-long sub-seasonal simulation at relatively coarser resolution (dependent on introduction of scale-aware physics). To achieve superior performance of NGGPS, the optimal combination of different physical parameterizations or options may depend on the forecast application. Even if the same scheme is used for different purposes, parameters for that particular physics scheme may need to be optimized for respective resolutions or addressed via scale-aware parameterizations.

There is a strong interest from both the weather and climate modeling communities in the continued development and improvement of PPs. On one hand, a significant fraction of the WRF user community is actively engaged in the development and testing of PPs for the prediction of mesoscale weather systems, including hurricanes and heavy rainfall events. On the other hand, Climate Processes Teams (CPTs), funded by multiple agencies (e.g., NSF, NOAA, and NASA), were established to study the various climate processes and to properly represent these processes in climate simulation models. Based on the response to the various R2O Initiative AOs, approximately 20 projects have been selected from universities and NOAA laboratories for funding by the NGGPS Program Office that have the potential to contribute to the further development of various aspects of GFS physics. Establishing an effective R2O process to ensure physics development efforts, either funded by NGGPS or by other sources, contribute directly to the continued development and improvement of NGGPS is a significant challenge.

To facilitate the R2O process for PP in support of NGGPS, the DTC proposes to evolve the current generation of GFS physics suite into a Common Community Physics Package. Working with the developers, the DTC will establish the infrastructure necessary to facilitate efficient and effective distributed development of PPs and testing and evaluation by the community to advance PP development. The DTC will also perform independent testing and evaluation of innovations of various physics processes that show promise to assess its potential for operational implementation (in support of different applications of NGGPS). While each of these aspects are discussed separately below, each component is important to the overall success of this task and will require close interactions between all team members involved in Task 1.

i) Initial Common Community Physics Package

A modular physics suite accessible both on-line as part of a prediction model, and off-line for isolated testing, will enable physics innovation and contribution from the broader community. As the research community engages in research to develop scale-aware physics or more complete microphysics, among other advancements, U.S. operational weather prediction centers can be poised to capitalize on it. Several steps are needed to produce and maintain a physics package that is scientifically justified and supports efficient R2O going forward. The GFS physics suite is currently entwined in a legacy set of code. To facilitate contributions from the broader community, the code needs to be refactored to be modular so that individual components (e.g. PBL, deep convection, etc) can be isolated for testing, or replaced. As part of a refactoring, consistency amongst the components should be enforced. For example, the radiation and microphysics schemes should use the same classes and distributions of relevant particles. Researchers should be able to interrogate input and output from individual physics schemes, and also tendencies. Momentum and mass budgets and conservation properties can then be quantified. Finally, infrastructure and data sets are needed to drive the physics off-line, so that changes can be rapidly measured.

For this first year, the DTC is proposing to work with EMC to transition the current GFS physics suite (or upcoming version with new interface for NGGPS) into the initial Common Community Physics Package (CCPP). The first step in this transition process will be to agree upon protocols for how all fields will be handled across the various packages and coding standards, as well as a design for the CCPP. Testing protocols will also need to be established to assure that the refactoring work does not have unintended impacts on the GFS physics suite. Once this important step is completed, the DTC will work with EMC to implement these critical changes to the package. This part of the CCPP work will be a major undertaking during the first year of the GMTB. Once the initial capability is in place, the focus will turn to maintenance of the package and supporting the addition of new innovations.

ii) Code management

Establishing and maintaining an effective code management structure is critical for an effective R2O process. Central to any effective code management plan is a code repository maintained under version control software. Building on its past experience, the DTC will work closely with the Global Modeling Branch (GMB) to establish a code management plan for the CCPP. This plan will include coding standards, version control protocols for checking new development into the CCPP repository and regression testing. Another key component of this plan will be establishing a Physics Review Committee that will be responsible for reviewing and approving changes to the physics package. Success of this process will depend on determining the appropriate membership of this committee and the protocols this group will follow.

iii) 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, helpdesk support and tutorials. The DTC will work closely with EMC to develop detailed documentation for the GFS physics suite, as well as any features included in the initial distribution of the CCPP. The DTC will also establish a CCPP Users Page, which will serve as an access point for both the CCPP documentation and periodic releases of the CCPP. An email helpdesk will be established. In addition to these utilities for the broader community, the DTC will also provide documentation and support on the proper procedures for channeling development into the code repository to those physics developers who want to work directly with the CCPP code repository. This additional support will strive to ensure that all developers use the same reference code and understand the proper procedure to channel their development into the next release of the physics package.

iv) Physics Testbed

To facilitate the development of different areas of physical parameterizations, it is critical that the testing and evaluation performed by each PP SWG be as uniform as possible. Infrastructure functions, including scripting, code management, diagnostic tools, offline component simulators such as a single-column model (SCM) and verification data sets, must be supported to provide a uniform 'test harness" to enable in-depth investigation of various physical parameterizations. The DTC will establish a Physics Testbed following the model of the DTC's Mesoscale Model Evaluation Testbed (MMET). The Physics Testbed in Year 1 will be for the model only, with the addition of data assimilation in Year 2 depending on resources available to the DTC. Specifically, the DTC will develop the necessary infrastructure and tools, and assemble the test data sets to support the testing of PPs by the SWGs, both in a single-column modeling framework, as well as the full model testing framework.

v) Testing and evaluation of innovations in physical parameterizations

Through collaboration with EMC, the DTC will also perform independent testing and evaluation of promising upgrades to existing physics modules or new physics modules to assess their potential for operational implementation. The testing will use the Physics Testbed protocols and infrastructure discussed in the previous item. The DTC will develop each physics test plan in coordination with EMC, and the test will be conducted upon the approval of the NGGPS Program Office. All tests will be conducted in close collaboration with the developers of the innovations and/or with Subject Area Experts.

Deliverables:

- Initial Common Community Physics Package

- Code management plan and community support for Common Community Physics Package
- Initial implementation of Physics Testbed
- Report on preliminary PP evaluation (to be expanded in Year 2)

Task 2: Code Management and User Support for Interoperable Physics Driver

Providing common physics suites that will properly interface with the dynamic cores currently being considered for the NGGPS will be key to conducting carefully-controlled tests that will play a role in the selection process. Kalnay et al. (1989, *Bull. Amer. Meteor. Soc.*, 620-623) put forth guidelines or rules to help facilitate the interchange of Fortran subroutines for PPs that have been widely adopted over the past 25 years at many operational (NWP) centers and within the research community. Since these rules were formulated, computational hardware and software needed for operational NWP have changed considerably. The multi-agency Physical Interoperability (PI) group, which was formed as part of the National Unified Operational Prediction Capability (NUOPC), was tasked with updating these rules to address these new technical challenges. In support of NGGPS, EMC is developing an initial physics driver capability based on the requirements set forth by the PI Group, which is scheduled to be available in June 2015. Once this initial capability is available, the DTC proposes to work with EMC to package the driver for release to the community. Packaging for release will require initial testing of the physics driver and filling any gaps in the documentation needed to support this capability to the model developers participating in the dycore Level 2 testing. In addition, the DTC will work with EMC to provide user support to these groups as they connect the common physics driver to their modeling system. Problems encountered during this process will likely lead to the need for updates to the physics driver. As with other software packages supported by the DTC, the DTC will work with EMC to determine the appropriate fixes. As physics development progresses, this driver will likely need to evolve to meet the needs for information exchange between the dynamic core and the physics packages. To meet the needs of this on-going development, the DTC will work with EMC to establish a code management plan for the common physics interface. This code management plan will include rules for updating the repository and testing requirements for assuring updates to the repository do not have unintended consequences.

Deliverables

- Code management plan for interoperable physics driver
- Documentation and helpdesk support for interoperable physics driver
- Standalone physics driver released to dycore participants

Task 3. Integration, Testing and Improvement of a Sea Ice Model for NGGPS

With the need to support forecasting with durations varying from a few days to one month, the optimal choice of an ice model for NGGPS is not obvious. The Los Alamos ice model (known as CICE) is a well-established community climate ice model that is included in the NCAR Community Earth System Model (CESM) and is used in various climate simulations. However, its performance for shorter-range weather forecasting is not known. In contrast, HYCOM already has an inexpensive "energy-loan" sea-ice model used up to this point for HYCOM applications for the US Navy and NOAA. Another inexpensive option is a simple ice model now under development at NCEP (KISS - Keeping Ice'S Simplicity). Two other sea ice model candidates are the Great Lakes Environment Research Laboratory (GLERL) ice model and the GFDL climate sea ice model. Clearly, to keep pace with the NGGPS development, NGGPS needs to develop a strategy on sea-ice modeling. This strategy needs to include selecting a baseline sea ice model, and incorporating it into the NEMS framework, so that it can be properly coupled with the other NGGPS component models. The sea ice model also needs to be supported to the broad user community through appropriate documentation, a code management plan, tutorials, and helpdesk support. To keep pace with the NGGPS development and its requirements, this sea ice model will need to evolve to include the appropriate physical processes for the time-scale of its application. As new sea ice models are developed, or existing ice models are improved, testing and evaluation needs to be performed, to support decisions on annual upgrades.

As a first step in developing a community sea-ice model for the NGGPS, the DTC will work with EMC to organize a workshop that will bring together representatives from all groups pursuing research related to sea ice forecasting. Engaging the research community from the very beginning of this process will maximize the potential for broad participation in the advancement of this community model. The planning committee will consist of sea-ice experts from NCAR, ESRL and EMC, as well as a representative from the university community. Workshop participants will be tasked with reviewing the status of the various candidate sea-ice models and assessing their potential to serve as a baseline sea ice model for the NGGPS. The planning committee will prepare a workshop report, which will include recommendations to the NGGPS Program Office with regards to the strategy for sea ice modeling for NGGPS and the selection of a baseline model.

Once the baseline sea ice model is selected, the DTC will work with the appropriate developers to transition this model into a community sea ice model to be incorporated as a component of NGGPS. This process will include determining what work is required to establish the selected model as a community model (e.g., availability of documentation, portability, compatibility with NEMS) and establishing a code management plan that will facilitate distributed development of the model. The DTC will also conduct testing and evaluation as appropriate to facilitate the R2O process and to support the annual upgrade of sea ice model component.

Deliverables:

- Recommendation on sea ice model baseline
- Code Management plan for sea ice model
- Initial implementation of sea ice model code management
- Demonstration test of sea ice model within a global application using NEMS coupling
- Planning for sea ice community support to start on Year 2

Task 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 NGGPS tasks and activities. For example, the transition of the GFS physics suite into a Common Community Physics Package and to support it to the community will require a lot of coordination with EMC and physics developers.

To support the continued development of NGGPS, it is desirable to hold community meetings and workshops. For example, in January 2015, the DTC collaborated with the NGGPS Program Office to hold a "*Workshop on Parameterization of Moist Processes for Next-Generation NWP Models*". It is anticipated that similar community workshops will be needed for various areas of the modeling system. For example, workshops on sea ice modeling, data assimilation, and ensemble systems will be critical to implementing this complex end-to-end system. Once NGGPS is fully implemented, workshops will be needed on model evaluations and model inter-comparisons. The DTC will support these community workshops and meetings at the request of NGGPS Program Office.

For this first year, the DTC is proposing to host two workshops: the sea ice model workshop, discussed under Task 3, and a Physics PI workshop that would bring together all researchers funded by NGGPS to work on PP improvements. This follow-on physics workshop will be critical to establishing buy-in to the code management plan and establishing a working relationship with these developers. The logistical support for these community outreach events is represented under the budget for Task 4. Travel support for invited speakers is included in the budget for the sea ice model workshop since the goal for that workshop is broad participation from the community. Travel support for the physics workshop participants is not included in the budget for this workshop because these researchers are already receiving NGGPS funding.

A moderate amount of program reserve will be held at the DTC Director's Office, to support the requests of NGGPS as need arises.

Deliverables:

- Sea Ice Modeling Workshop
- NGGPS Physics PI Workshop
- Quarterly reports on overall progress of NGGPS-funded activities