Report of the Science Advisory Board (SAB)
of the Developmental Testbed Center (DTC)

November 27, 2015

Introduction

A DTC Science Advisory Board meeting was held during 16-18 September 2015 at NCAR in Boulder, Colorado. The SAB's charge is to provide advice and insight on strategic goals for the DTC. This report serves as a summary of the discussion that occurred during this meeting, and the recommendations that we formulated.

The DTC serves as a bridge between the operational and research communities. This is a two-way interaction, consisting of both operations-to-research (O2R) and research-to-operations (R2O) activities. The O2R component consists of providing operational NWP software and support to researchers, which enables the development of innovations for possible implementation in operations. As part of the O2R effort, the DTC organizes workshops and tutorials and provides helpdesk support. DTC's R2O efforts include, but are not limited to, testing and evaluation (T&E) activities involving DTC staff and scientific program visitors.

The scope of DTC's activities will likely change in the future owing to the relatively new Next Generation Global Prediction System (NGGPS) initiative, which seeks to replace the operational Global Forecast System with a single, unified global coupled model. The Global Modeling Test Bed (GMTB) is being established within DTC to foster community involvement in the NGGPS. The atmospheric physics module of the NGGPS is termed the Common Community Physics Package (CCPP). The GMTB is slated to play a key role in its development.

Following our general recommendations, which are either broadly applicable or involve more than one area of responsibility, we consider each of DTC's task areas in turn.

General recommendations

The SAB recognizes that the DTC's responsibilities exceed its available resources, both in terms of staff time and computing and storage facilities. Staff time is largely consumed by support activities, which limits their ability to conduct T&E relating to the operational software they support. Without question, the support effort is a crucial, core activity, but we strongly believe that T&E activities are vital to DTC's mission and an integral part of their R2O charge not only because they enhance the staff's ability to support the NWP software but also because as they help demonstrate DTC's impact on operations. However, T&E activities require staff time, and so we reiterate our previous recommendation that DTC staff be given adequate time for scientific research.

When demands exceed the available supply, some kind of prioritization is indicated. Along those lines, last year we recommended that the DTC revise its Visitor Program to proactively identify research collaborators in the community who can facilitate DTC's R2O and T&E activities, and invite them to submit research proposals. We also advocated for a ticketing system to monitor and demonstrate support activities. Both of these recommendations have been accepted and at least partly implemented. In particular, we believe the assessment of support efforts may help DTC identify activities of lesser importance, and perhaps to justify their discontinuance.

This is especially important as it is clear that the demands on DTC's resources will continue increasing and the its areas of responsibility will not cease expanding. A timely example is the GMTB initiative that has emerged in the last year. During the 2014 SAB meeting, the prospect of DTC involvement in global modeling efforts was seen as inevitable but also not immediate. As a consequence, we recommended that only "modest investments" be made in anticipation of global models, as DTC's traditional strength has been in regional innovations, particularly at high spatial resolutions.

However, the advent of the GMTB, which suddenly represents a sizable portion of the DTC's present and immediate future budgets, has accelerated the timeline considerably. Concerns were expressed that this new global modeling effort could represent a distraction from necessary current activities. However, we also recognized that, particularly with the advent of global models like MPAS, the boundary between global and mesoscale models is dissolving rapidly. Thus, we also see the GMTB as an exciting opportunity to position the DTC at the leading edge of a new frontier.

Given its charge to be a bridge between operations and research, we also discussed the DTC's involvement with the NCEP Environmental Modeling Center (EMC) Model Evaluation Group, the Joint Center for Satellite Data Assimilation (JCSDA) and other testbeds, with forecasters and NWS SOOs (Science and Operations Officers), and with recipients of NWS CSTAR (Collaborative Science, Technology, and Applied Research) grants. Given its increasing acceptance in the operational community, the DTC's Model Evaluation Tools (MET) package could provide ways and means for accomplishing this. This effort could expose important research opportunities that might otherwise go unnoticed.

To summarize, our general recommendations include:

- Tasks need to be be prioritized based on usage and expected impact, to identify activities that are lower priority in a resource-limited environment. The ticketing system should be useful for the prioritization.
- T&E activities are crucial to DTC's mission, and should be encouraged and supported. Specifically, this helps DTC demonstrate impact on operations and enhances their support activities. This applies broadly across all DTC tasks, but especially with regards to data assimilation and hurricanes. Last year, we

recommended that DTC staff be given more time for scientific research, and that remains a high priority.

- We believe that DTC as a whole cannot get too focused too soon on global models at the expense of their other important duties. At this time, their strength lies with regional innovations. That said, we suggest they keep in mind that today's regional resolution is tomorrow's global resolution, and therefore a continued focus on high resolution T&E activities is appropriate.
- We suggest DTC establish and/or improve connections with EMC's Model Evaluation Group (MEG), the Joint Center for Satellite Data Assimilation (JCSDA) and other testbeds, as well as with forecasters and SOOs. Given its increasing acceptance in the operational community, the MET package could provide ways and means for accomplishing this.
- More computing and storage resources are needed to support DTC activities. This should not be a chronic limitation.
- We recommend reaching out to university PIs who have CSTAR proposals, as they could create valuable projects for the visitor program.
- We suggest identifying individuals with global modeling expertise to serve on the SAB, given the advent of the GMTB.

Specific Task Areas

There is a lot of overlap among the core responsibility areas of DTC, which complicates the clean delineation of recommendations by specific task. As a consequence, there is some redundancy in the task-specific discussion and recommendations presented below. That said, we believe that this should be recognized as a strength and a source of mutual support. The inarguable goal of any program is to exceed the sum of its parts.

(a) Verification

Many of our recommendations for this task area focus on increasing community awareness and use of the MET package for model verification. This package is very powerful but it also has a steep learning curve. We believe many users find the rich catalogue of available tools and procedures daunting, at least at first. Many other potential users appear to be unaware of MET's capabilities, or even the package's existence.

A necessary step to increasing usage of MET is to enhance its visibility. We suggest augmenting current community outreach efforts with a proactive approach along the lines of the Unidata model. Unidata has been very successful at conducting workshops "in the field" hosted by university partners. Visibility for MET could also be enhanced via AMS short courses. Naturally, this would require support for staff time and travel. A real-time web presence showcasing MET-based verification, perhaps in combination with existing real-time modeling efforts available elsewhere, could be useful to enhance visibility.

A second step is to make sure that existing and prospective user needs are being met by the MET package. We therefore recommend that DTC actively poll active and prospective users regarding their requirements and priorities. It is particularly important to identify persons who could or *should* be using MET, but are not, to ascertain why they are not doing so. DTC could possibly access this broader community via the WRF and Unidata community mailing lists. The regional workshop idea recommended above might also facilitate this effort.

MET is making inroads into the operational NWP community, and thus we recommend developing or enhancing connections with NWS forecast offices. Additional pools of new users can be established by identifying specific groups that could also particularly benefit from MET. As a specific example, it appears that few people associated with JCSDA are aware of MET, and those that are appear to be less than fully informed about its capabilities. Other potential new user bases include the National Water Center and the storm-scale community, both of which appear to be largely unfamiliar with the verification package. Participation of DTC staff in meetings such as the Severe Storms and Mesoscale conferences could be considered.

Regarding MET developmental priorities, we strongly support the development of new tools for ensemble verification, given the rapid increase in interest in, and importance of, ensemble forecasting. This particular recommendation will be repeated several times in the discussion that follows.

To summarize, our recommendations regarding verification include:

- We suggest that DTC can popularize and support verification in general and MET in particular through community outreach, such as regional workshops and AMS short courses. Unidata has been very successful in conducting regional workshops hosted by university partners.
- To further acceptance of MET, we also recommend that DTC actively poll users regarding their requirements and priorities. However, it is also necessary to query beyond the existing user base, who are likely being served well. Instead, DTC could survey all WRF and/or Unidata all community users, to ascertain why they are not using MET. The workshop idea above would facilitate this effort. We suggest that DTC work with JCSDA on satellite verification and data assimilation, contact the National Water Center, and connect with the storm-scale community, as representing pools of potential new users.
- We suggest that DTC develop a real-time web presence showcasing MET-based verification, and/or leverage & popularize existing efforts, as a way of enhancing familiarization with and interest in MET.
- We recommend working towards developing a set of best practices for using MET, especially including visualization and reporting of verification statistics.
- We recommend that a portion of NGGPS funding be used to support global applications of MET.
- We recommend developing connections to forecast offices, now that they are using MET.

- We emphasize that ensemble verification is a high priority.

(b) Data assimilation

The Data Assimilation (DA) task area is one where the imbalance between demand and resource supply is particularly acute. The SAB believes that the DA team is supporting too many models with too limited resources. One way to mitigate this is to synergize better with the mesoscale and hurricane task groups, in order to leverage resources. However, that is probably far from sufficient. We recommend that DTC determine how many people are using which tools, with an eye towards identifying items that can be declared obsolete.

Another way of leveraging limited resources is to involve visiting scientists in designing new T&E activities. We recognize that there is no funding for such activities at the present time, and thus new sources of support need to be sought.

Researchers need to get the same data and preprocessing capability employed in operational models so they can do their R2O properly. This has been a recurring topic of discussion at recent SAB meetings, and continues to be a crucial concern. We appreciate that there is a subset of data that are restricted and cannot be made available. However, a key issue is researchers outside the NOAA firewall do not even have access to data that are fundamentally unrestricted. We do recognize that DTC cannot help mitigate these problems without additional resources.

As last year, we recommend that DTC continue facilitating community participation in the ongoing Gridpoint Statistical Interpolation (GSI) code refactoring (modernization) initiative. Specifically, we suggest collaborating with the Joint Effort for Data Assimilation Integration (JEDI) effort to unify DA architecture to make more model-agnostic DA tools.

To summarize, our recommendations regarding DA include:

- The DA team supports too many models with too limited resources. One way to mitigate this is to synergize more with the mesoscale and hurricane task groups, in order to leverage resources. Another is to identify and de-emphasize tools that appear relatively unused and/or obsolete, to economize on support costs.
- We recommend involving visiting scientists in designing new T&E activities. We recognize that there is no funding for such activities at the present time, and so urge that new sources of support be sought.
- Researchers need to get the same data and preprocessing capability employed in operational models so they can do their R2O properly, and need help gaining access to data that are unrestricted but not easily available.
- We recommend continuing efforts regarding the GSI code refactoring, and suggest collaborating with the Joint Effort for Data Assimilation Integration (JEDI) effort to unify DA architecture make more model-agnostic DA tools.

- We recommend DTC continue working with operations in supporting 4D EnVar, as this is needed to support R2O.

(c) Hurricane

The DTC occupies a central position between EMC and the research community external to NOAA, specifically and primarily via the Hurricane WRF (HWRF) system, which continues growing in both usage and complexity. DTC's hurricane work includes supporting HWRF users in the research community (via code management, documentation, helpdesk and tutorials) and conducting T&E to identify and develop improvements for the operational model.

Regarding HWRF, we recommend that DTC continue with the HWRF basin-scale hurricane modeling efforts with the community and with HFIP, as this has the chance of making material R2O contributions. As last year, we believe it is not fruitful at this time to put resources into adapting the current operational NMMB (Nonhydrostatic Multiscale Model on B-grid) model for hurricane applications. This is justified by the NGGPS initiative, which seeks to completely overhaul NCEP's current operational modeling suite.

Regarding NGGPS, we fully support DTC's efforts towards incorporating hurricane-specific model physics into the next generation model's physics package (CCPP) that is currently under development. Given the future shifts in operational hurricane modeling that are assured at this point, a model-agnostic approach to model physics and initialization is needed for the longer term.

In the past, the SAB has lamented the constraints on T&E activities that have demonstrated value with respect to R2O, including the lack of staff time for scientific research and limited access to computing facilities. We recommended using the Visitor's Program to "target" scientists who could enhance T&E efforts and ensuring that DTC staff have sufficient time to make the visitor collaborations effective. These remain priority items. Additionally, DTC has been fruitfully pursuing T&E activities regarding microphysics and radiation for several years now. We recommend that T&E activities regarding model physics be expanded, for example to include planetary boundary layer (PBL) schemes and other model physics, and to involve visiting scientists in this effort.

To summarize, our recommendations regarding the hurricane task include:

- We support DTC's efforts towards incorporating hurricane-specific model physics into the CCPP framework that is currently under development for NGGPS, and recommend that taking a model-agnostic approach to model physics and initialization is appropriate.
- We recommend that DTC continue with the HWRF basin-scale hurricane modeling efforts with the community and with HFIP, as a priority item.

- We recommend DTC continue working with the operational group at EMC regarding model testing and upgrades.
- We recommend that hurricane T&E activities regarding model physics be expanded to include other model physics, such as PBL schemes, and involve visiting scientists in this effort.
- We believe that it is premature for DTC to put resources into NMMB for hurricane tasks at this time.

(d) Mesoscale modeling

The mesoscale modeling task includes T&E activities that has involved WRF-ARW, WRF-NNM and NMMB, and developing and maintaining the Mesoscale Model Evaluation Testbed (MMET), which provides a library of case studies to the community. Regarding T&E, we maintain that considering convection-allowing ensembles is a high priority. This would be a computationally burdensome activity, so we suggest that DTC investigate leveraging what other groups are doing regarding high-resolution ensembles. As an example, mining Hazardous Weather Testbed (HWT) modeling data could be a way of obtaining high-resolution information created by other groups.

We also recommend that the DTC can play an important role in facilitating the development of ensemble post-processing tools as this would be of particular value not only to the community but also to the mesoscale modeling task's T&E efforts. We suggest that further investigation of aerosol-aware physics is a worthy topic for future T&E experiments.

The SAB sees value in MMET but is concerned with its lack of visibility. MMET should be brought to the attention of SOOs and might also benefit from the cultivation of a group of enthusiastic users who can contribute to and advocate for this effort. We also recommend the inclusion in MMET of more cases highlighting model skill drops. One hindrance to greater visibility may be its acronym, which is easily confused with MET. We also recommend that active connections be made with EMC's Model Evaluation Group (MEG).

To summarize, our recommendations regarding the mesoscale modeling task include:

- The SAB sees value in the Mesoscale Model Evaluation Testbed (MMET) but believe this effort lacks visibility.
- We suggest expanding the MMET to include global case studies as a way of leveraging the future focus on global models operated at mesoscale resolutions.
- We further suggest that the acronym MMET be reconsidered, as it appears to be a source of confusion (with MET).
- We also recommend the inclusion in MMET of more cases highlighting model skill drops, including extension to global models.
- We recommend investing in T&E of convection-allowing ensembles and suggest that DTC leverage what other groups such as the HWT are doing regarding high-resolution ensemble modeling.

- In our opinion, aerosol-aware physics remains an opportunity for T&E tasks.
- As part of the increased importance of ensembles, the facilitation of ensemble post-processing is a key goal and DTC can play an important role in this effort.
- The SAB envisions that the mesoscale modeling and ensemble tasks will be fully merged sooner or later, owing to their natural synergy.

(e) Ensembles

The ensemble task effort in the last two years has been principally aimed at supporting the North American Rapid Refresh Ensemble (NARRE), which will be implemented operationally in 2017. In addition to software and workflow tasks, this has entailed testing of stochastically-perturbed physics and model fields in the Rapid Refresh (RAP) configuration of WRF-ARW, which as a spatial resolution of 13 km. This work is ongoing and appears to have a clear path forward.

In our discussions, SAB members expressed support for continuing research in stochastic physics and techniques for infusing random perturbations in model fields such as SKEBS (stochastic kinetic-energy backscatter scheme). While current work is targeted to the 13 km resolution of the RAP model, which retains validity owing its applicability to current global modeling, we recommend investing some resources in convection-permitting resolutions as a way of staying ahead of the curve. The SAB sees the DTC in general, and the ensemble task in particular, as having important roles to play in the development, enhancement and dissemination of ensemble post-processing techniques. Data mining, machine learning, and ensemble calibration are areas that are important but not widely appreciated, and DTC could serve an important role in popularizing them.

To summarize, our recommendations regarding the ensemble task include:

- We support continuing research in stochastic methods (e.g., stochastic physics and SKEBS, etc.) and leveraging development in the GSI ensemble development effort.
- We support shifting research towards convection-permitting resolutions, which can include leveraging existing efforts such as the HWT, as discussed previously, recalling again that global models are moving towards mesoscale resolutions.
- We emphasize, however, that resolution testing at grid spacings such as 13 km is still valid owing to applicability to current global modeling.
- We recommend engaging the research community with respect to post-processing techniques and probabilistic products, e.g., for high-resolution applications such as convection-permitting ensembles.

(f) The Global Model Test Bed

We recognize the GMTB as an important new initiative but also one in its very earliest stages, so our considerations and recommendations are limited in scope. At the

outset, the GMTB is tasked with a key role in the development of the common physics package CCCP along with its Interoperable Physics Driver (IPD) for the next-generation global model, NGGPS. It is also responsible for organizing a workshop on sea ice physics.

The GMTB task came up repeatedly in discussions of the DTC responsibility areas, and could represent a way of enhancing how the various parts of DTC interoperate. There are at least several ways that the GMTB can enhance synergies among the DTC's various responsibility areas. The CCPP would be enhanced by the incorporation of model physics appropriate to hurricanes and mesoscale weather applications (such as the HWRF and RAP models). The DTC can use its bridge role to help developers accomplish this. The verification, hurricane, mesoscale modeling, and ensemble task areas require new or improved ensemble post-processing techniques, and the latter three would benefit from further development of scale-aware and stochastic physics. The GMTB itself could potentially serve as a bridge to coordinate (and possibly fund) efforts by the other task areas.

The last several SAB reports envisioned a future in which the DTC moved into the realm of global modeling. That day has finally arrived. Certainly, the accomplishment of the technical aspects of the GMTB work will be challenging. Finding areas of synergy between the emerging global focus and the DTC's traditional strength in regional-scale innovations also represents a challenge, albeit one of a different nature.