**Summary of DTC Science Advisory Board Meeting**

1. **Introduction**

A DTC Science Advisory Board (SAB) meeting was held on 25-27 September 2013 at the NCAR Foothills Laboratory in Boulder, Colorado. Bill Kuo opened the meeting by reviewing the charge of the DTC SAB. According to the DTC Charter, the primary functions for the SAB are: (1) providing recommendations for strategic directions for the DTC, (2) providing recommendations for new codes or new NWP innovations for DTC to perform testing and evaluation, and (3) reviewing DTC Visitor Program proposals, and providing recommendations for selection. Bill stressed that the focus for the DTC SAB meeting is to discuss new NWP innovations that DTC should consider testing in the coming three years for possible transition to operation. The DTC SAB meeting is not meant to be a “DTC Program Review” meeting, which would require a different set up.

Bill Kuo then gave an overview of the DTC, covering (i) the mission, history and governance of the DTC, (ii) the AOP 2013 tasks and budget, (iii) planning process for DTC AOP 2014, (iv) the 2012 SAB recommendations and DTC responses, and (v) challenges and opportunities. Louisa Nance presented DTC’s efforts on community support of software systems, community outreach activities, and the DTC Visitor Program. This was followed by presentations by DTC Task Leads on DTC task areas, including mesoscale modeling, hurricane, data assimilation, ensemble, and verification. These task presentations discussed the major accomplishments over the past three years, the on-going efforts, and preliminary thoughts for future DTC activities.

The primary mission for DTC is to be a bridge between operation and research NWP communities. For DTC to serve this role effectively, it is important that there is a good dialogue between the two communities, particularly on topics related to the planning of future DTC activities. For this reason, we invited Geoff DiMego and Vijay Tallapragada to present future plans for mesoscale modeling and hurricane modeling at NCEP/EMC and Mike Horner to give an AFWA modeling update. These presentations were very informative, and stimulated considerable discussions.

The oversight of the DTC is the responsibility of the DTC Executive Committee (EC), which consists of senior management from NWS, OAR, Air Force, and NCAR. John Murphy, Chair of the DTC EC, presented NWS’s view on research to operation and the role of the DTC. He stressed that the primary NOAA customer for the DTC is NCEP/EMC, and the success of DTC is judged based on the extent to which DTC activities result in improvement to NOAA operational models. Col. John Egentowich, also a member of DTC EC, gave his perspective on the role of DTC in Air Force Weather. Col. Egentowich emphasized that Air Force is committed to the community modeling paradigm. DTC serves two important purposes from Air Force perspective: (1) it mitigates test and evaluation shortfall in AFWA resources, (2) it facilitates new science and technology into Air Force operation.

SAB members then presented their views on the future directions of NWP technologies that are relevant to DTC, and provided recommendations for DTC to consider for testing and evaluation. The SAB presentations were followed by considerable discussions. A summary of these discussions is presented in the following section.

1. **Summary of discussion on DTC tasks**
   1. *Mesoscale Modeling (prepared by Jamie Wolff)*

**Modeling Systems**

Geoff DiMego presented the EMC roadmap on mesoscale modeling. With enhanced computing resources made possible by the Sandy Supplemental funding, forward-progress in system implementation is now possible. The modeling systems for the foreseeable future will continue to be WRF-ARW and NEMS-NMMB based. Configurations of each model will be the basis for future mesoscale and high-resolution (convective-permitting) ensemble systems.

Mike Horner gave an update on AFWA modeling. While the top priority for AFWA is cloud forecasts, regional, ensemble and aerosol modeling are also near the top of the list. AFWA is moving towards a transition to a single, multi-scale modeling system as early as 2016. In the meantime, incremental updates to their current WRF modeling system will be valuable.

Enhancing physics interoperability within NEMS-NMMB is a priority for EMC. DTC should work with EMC to discuss priorities on which physics packages are transitioned from the WRF infrastructure to NMMB and then work with physics developers to achieve the integration. Questions still exist regarding the role of preliminary testing in the WRF infrastructure prior to expending significant resources on integrating new packages into NMMB. Are test results from WRF relevant in terms relative performance in NMMB? These questions need to be addressed.

**Testing**

A more direct collaboration with the HRRR developers should be pursued. This model (ARW configuration) will be a core system used in operations at NCEP (HRRR/HRRR-E). It will become a key configuration to test as we move towards convective-permitting (~3km) resolution in the near term and storm scale (<1km) resolution in the long term.

Continued focus on physics testing is a priority. As we move towards high-resolution modeling systems, more testing will be needed (especially in the area of PBL and shallow convection parameterizations) to identify packages that work well at those scales. Emphasis should be placed on how packages operate together; better coupling of physics schemes is important.

In order to quickly expose systematic model biases, fully cycled testing should be employed. This type of testing would assist with diagnosing areas for further investigation, not necessarily informing the operational centers on the benefits of including fully cycled systems in operations.

With the future moving towards unified models, scale-aware physics will come to the forefront. It is unclear exactly what is available in the research community at this time. Better connections to international workshops should be pursued to connect with that community. In addition, variable resolution modeling systems (e.g., MPAS, FIM/NIM) should be considered for testing scale-aware physics schemes.

Several SAB members suggested that the DTC should focus on the 2-4 year horizon for operational implementation. This will allow for more opportunity to identify a “better scientific approach”, rather than limit work to current operational configurations only.

**Evaluations**

An emphasis will need to be placed on utilizing more advanced tools for high-resolution model output. Traditional metrics do not meet the needs at those scales. There is a lack of tools for evaluating severe weather parameters. Perhaps it would be beneficial to engage more closely with HWT and/or HMT again to leverage the datasets available, educate the community about tools available in MET, and use the opportunity to understand what is lacking and develop new metrics (or apply existing tools in a new way) that would benefit those entities.

**Community Interactions**

Continued effort needs to be made to spread the word about MMET (Mesoscale Model Evaluation Testbed) and make it an effective facility for the community-at-large to use. We should continue to include current, relevant cases. Adding a cycling capability to the MMET cases should also be considered.

Several SAB members expressed interest in hosting another physics workshop. The feedback obtained during the last workshop (June 2011) was very valuable and the conversation should be continued/sustained, if possible. Some possible focus areas to consider are scale-aware and stochastic physics in order to assist with moving the field forward in those specific areas. It was also suggested that the DTC should connect to other workshops already being planned/held elsewhere to establish connections.

To what extent should the DTC support O2R for NEMS/NMMB? Geoff DiMego’s recommendation is to engage the community on the use of NMMB through a friendly user tutorial. This will require some basic user support be established through a user guide and webpage at a minimum, and possibly a help desk, as well.

The ECMWF-like community model-testing infrastructure was discussed as something that continued to be an area of interest for some members as a way to assist the community in running the operational configurations. There is still a question as to what the current target system would be for this. For AOP 2013, a proposal was made to begin a planning effort for such an infrastructure. This was not funded due to budget constraint. EMC would like this to be considered for AOP 2014.

* 1. *Ensemble (prepared by Isidora Jankov)*

DTC Ensemble Task infrastructure is designed to facilitate testing and evaluation of new techniques and capabilities for all specific components of the ensemble system. These components include ensemble design, post-processing, products, and verification. To accommodate all components, we came up with the infrastructure that consists of six modules. Module 1 focuses on an ensemble configuration with Module 2 and 3 as sub-modules dealing with perturbations in initial conditions and model physics, respectively. Module 4 serves for testing and evaluation of various ensemble post-processing techniques. Module 5 focuses on various ensemble products, displays and decision-making tools, and Module 6 deals with ensemble verification.

Recently, DET has been mainly focusing its efforts on ensemble configuration related questions (Modules 1, 2, and 3). During the SAB meeting we learned that there is a strong interest for DET to contribute in other system components. The SAB encouraged DTC to continue development of all six DET modules. The EMC is generally more interested in tests related to the Next Generation system, while AFWA and Weather Prediction Center (WPC) expressed strong interest in development of new ensemble related products and decision-making tools.

In terms of design of the Next Generation ensemble modeling system (Module 1), it will most likely consist of 3km grid spacing, national scale ensemble (primary focus) with 1km moveable nest for high-impact weather (secondary focus, longer term). Regarding uncertainty related to initial conditions, the DET (Module 2) will focus on testing and evaluation of available and promising techniques, such as, various dynamical downscaling options and Hybrid EnKF approach when ready. In terms model related uncertainty, a suggestion was mad to explore stochastic physics options for testing and evaluation.

Also, the SAB brought up testing and evaluation of cost-benefits related issues (e.g. optimal number of ensemble members, vertical levels, etc) as potentially important questions that will have to be answered in the next several years while working on the design of the new generation ensemble system.

Various platforms for DET testing were discussed. The idea is to utilize what is currently available:

* ExREF running in real-time at GSD
* SREF functionally similar environment available on Zeus super computer
* HRRR
* HIRES window in ExREF.

**More General Comments and Suggestions:**

Geoff Dimego suggested organizing a meeting that would involve Zoltan Toth, Stan Banjamin, Tom Hamill, Jeff Whitaker, Isidora Jankov and NCAR and academia representatives to discuss options of various components of the future generation ensemble system.

There is a need and interest in deepening collaboration between the Ensemble Task activities with Hurricane and Data Assimilation tasks.

The Field Alignment technique was presented at the SAB meeting as a new technique that has been explored and evaluated as a part of activities in Modules 4 and 5 of the DET. The technique also has a large potential for use in Data Assimilation. Expanding use of the Field Alignment technique to data assimilation arena ended up as a SAB recommendation.

Finally, the SAB suggested for the DET to stay involved with Testbeds (e.g. HWT, HMT…) and use data and lessons learned during various Testbeds to contribute to design of evaluated systems.

* 1. *Hurricane (prepared by Ligia Bernardet)*

**General Recommendations**

SAB recommended that the main role of the DTC should remain as the connection between the operational and research communities. DTC staff cannot and should not do all the development, create all the model capabilities needed for testing, and do all the diagnostics. Instead, DTC staff should work side-by-side with visitors and experts in the community to identify model deficiencies, implement innovations, and conduct tests.

DTC should strive to create an ECMWF-like infrastructure that supports researchers in code management and experimental design and configuration. This infrastructure should make it relatively easy to reproduce others’ experiments and understand exactly what codes, observations etc. were used to make the runs. Also, the Hurricane task needs to work synergistically with the Data Assimilation and Ensemble tasks, since all these aspects are critical for hurricanes.

**Modeling Systems**

While it is expected that HWRF will eventually become an NMM-B-based system in the NEMS framework, the transition is not expected in less than 3 years. Therefore, the DTC is encouraged to continue to work with HWRF solely in the WRF-NMM-E framework.

Based on the presentation given by Vijay Tallapragada, the planned configuration of HWRF in the NMM-B framework involves a global model with multiple moving nests. To prepare for this implementation, it is recommended that the DTC provide support to the basin-scale effort in the WRF-NMM-E framework. The basin-scale configuration consists of a large parent domain with multiple moving nests. The SAB recommends that DTC assist AOML/HRD in integrating the basin-scale development onto the centralized HWRF code, and prepare it for becoming a supported, optional configuration in the HWRF public release. It is important that the DTC continue to increase the flexibility of HWRF so that it can be configured in alternative ways for research. The basin-scale is an example of that, and additional flexibility should be sought in other HWRF aspects as well.

EMC plans to run HWRF coupled with downstream models in the near future (wave, storm surge, and inundation). Due to resource limitations, it was not recommended that DTC start working with those additional components at the moment. Instead, DTC can contribute in the areas of land surface modeling and precipitation forecast, as detailed in the next section.

While DTC’s main focus should remain the improvement of HWRF, DTC should not restrict itself to working only with HWRF. Important insight can be gained through diagnostics of HFIP Stream 1.5 and 2.0 models. One area that would be of interest is rapid intensification performance in the various models.

The SAB responded positively to questions regarding DTC involvement in diagnostics of the GFS model output to gain insight onto the decrease of track skill on days 4-5 of the forecast. This effort was requested by HFIP Program management.

**Diagnostics, testing and evaluation**

While DTC should invest more in diagnostics and evaluation to complement its testing activities, verification and diagnostic activities should provide feedback for developers about model deficiencies and avenues for improvement.Priorities for verification and diagnostics are precipitation, large-scale fields, radiative fluxes, sensible and latent heat fluxes, and model energetics.

DTC should engage in improvement of rapid intensification and rapid weakening (RI/RW) forecasts, an important HFIP goal for which little progress has been made.

Testing of promising new or improved physical parameterizations should remain a priority for DTC. Successful parameterizations are the ones that improve forecasts for generic areas and weather systems, as well as for tropical cyclones. Additionally, scale-aware physics, which can work in a model running both low- and high-resolutions, is a high-priority.

It is recommended that DTC interface with the HFIP physics (strategic and tiger) teams to define priorities for testing. Also, DTC should be abreast of scale-aware work and workshops ongoing in the international community, particularly in the area of scale-aware physics. It is important to consider physics suites, not isolated packages. The broad areas for prioritized testing are

* + Aerosol-aware microphysics and radiation parameterizations
  + Land surface model
  + Planetary boundary layer parameterizations
  + Stochastic parameterizations
  1. *Data Assimilation*

**Discussions on Other Task Areas Relevant to Data Assimilation**

Many of the discussions on other task areas are relevant to the DTC data assimilation task. It is anticipated that future NWP systems will cover a wide range of scales, from global to cloud-resolving. To facilitate research to operation transition, DTC also needs to engage itself on data assimilation activities that cover a wide range of scales, including support for models with variable resolutions.

According to the roadmap presented by Geoff DiMego, NCEP mesoscale modeling is moving toward higher resolutions (e.g., 1~3-km cloud permitting resolution). This will require support of data assimilation at such resolution. AFWA is planning to transition its data assimilation system from GSI to EnKF-GSI early next year. Analysis and short-term forecasts are priorities for AFWA.

To support the future development of HWRF (based on roadmap presented by Vijay Tallapragada), and the corresponding efforts on data assimilation are required:

* + 2014-2015: Inner core DA (TDR, satellite), cloudy radiance assimilation, two-Way regional Hybrid DA HWRF Ensembles
  + 2016-2017: Hybrid-EnKF DA, advanced vortex relocation procedure, improved GSI/Hybrid techniques, DA for moving nests

The anticipated implementation schedule is as followed:

* Q3FY14: One-Way Hybrid with inner core aircraft recon data (TDR/FL) and clear sky satellite radiance DA
* Q3FY15: One-Way Hybrid with inner core recon data (TDR/FL); clear and inner core cloudy radiance DA
* Q3FY18: Two-way hybrid 3D/4D En-Var with inner core aircraft and all sky satellite radiance DA

NCEP/EMC has expressed a strong desire to create an ECMWF-like community test infrastructure (including DA). Key elements for such infrastructure include build mechanism for users using shell scripts, and easy access to data sets and computing facilities for visiting researchers to conduct experiments (including cycling the system) and analyze results.

For testing and evaluation of mesoscale modeling system, the data assimilation should be included as part of the model T&E activities. Cycling data assimilation will provide more information about the model system errors. Information provided from O-B (observation minus background) is useful for verification as well.

**Data Assimilation Discussion**

A general direction of DA was suggested by the SAB. These items were also the items suggested in the 2012 SAB meeting since the trend of DA has not changed much. They should be considered for the long-term planning of the DA task:

* Estimating model uncertainty (e.g., ENKF, ensemble var, 4D-var):
* Sampling errors
* OSE, OSSE for data impacts
* Observation biases
* Cloudy analysis
* Non-Gaussianity in priors and observation errors: field alignment
* Observation QC
* Outer iteration in ensemble DA and hybrid: not yet in ensemble hybrid system
* Multi-scale DA: MPAS, variable model resolution

It was recognized it is not possible to stretch the team in every suggested area. Therefore, SAB recommended DTC to continue its current direction. If resources permit, a few items were suggested for the DA task to focus for AOP 2014:

* Testing regional EnKF.
* EnKF code management and community support for mesoscale/storm-scale.
* Model uncertainty, e.g. stochastic physics. It is recommended to test existing capability, instead of ongoing research capability.
* Field alignment: Interest was also shown from the EMC HWRF team. However, a concern was raised about a possible license issue that needs to be explored.
* Better use of regional radiance data.

NCEP HWRF team suggested that the DTC extend current GSI-hybrid work and build connection with the HFIP satellite team, by conducting some data impact studies. There were also questions regarding the role of the DTC in radiance DA, channel selection and digital filters. The SAB agreed that it fits into the DTC role to enhance current DA capabilities, one example is testing of non-local GPSRO operator in GSI-Hybrid.

Some interest was shown from the SAB related to using different ensembles for the GSI-hybrid. However, there was also a concern whether it is worthwhile to work on generalizing the GSI code for different ensembles, since GSI doesn’t generalize the background reading either. Currently, GSI reads global and regional background as well as ensembles using “if” statements.

Some of the SAB members showed recognition of the potential functional overlap between JCSDA and the DTC. However, it was strongly suggested that a discussion regarding this should be initiated at the management level. Currently, JCSDA is focused on global GSI and GFS, while DTC is focused on regional GSI and regional models. Earlier discussion between DTC and JCSDA management indicated that if DTC moves into global arena, JCSDA is interested in closer collaboration.

Regarding one of the DTC proposed tasking areas, making code modular and detached from applications/models, a concern was expressed this work may have huge impacts on the NOAA implementation (requiring NCEP to temporarily suspending implementation). Therefore, such effort should be initiated by EMC, instead of the DTC.

* 1. *Verification*

The discussion about verification provided a nice overview of the issues we are likely to be facing in three years with respect to both new modeling technologies and ongoing verification issues. In particular, we discussed uncertainty, spatial scale, data assimilation, new observation types, diagnostic verification tools, climatologies, and users needs. Many of the topics have come up before, but a few new ones were introduced as well, most notably the new multi-scale models that are under development. Finally, the importance and appropriate level of community support for both verification methods and tools was discussed.

**Verification Methods and Issues**

The discussion covered the big issues facing the verification community. Many questions were raised and remain unanswered by the research community. Thus, as solutions present themselves, they should be incorporated into the efforts of the DTC verification group. The questions include:

* How to estimate and incorporate uncertainty into verification?
* How to verify high-resolution forecasts? What about multi-scale models?
* With what methods / observations? What do we have for non-precip fields?
* How can we better incorporate temporal and spatial information into verification?
* How can we make verification relevant for more users?
* How can verification connect better with DA? They have similar issues in uncertainty, incorporating new observations, multiple scales.
* Is there value to doing DA-style pre-verification?

**User Needs**

At many points during the SAB meeting, the issue of differing user needs came up. Chris Davis asked if there was some way to incorporate more diagnostic capability in verification for modelers. Perhaps the DTC Verification team could help novice verification users by having a problem of the month or supplying predefined metrics for certain verification problems. Additionally, we could provide data packages to users. Mark Stoelinga stressed that he would like to see climatological studies completed with results made available to the public.

**Community Support**

Finally, the topic of hosting a verification workshop was raised. In the past, we held these workshops nearly every year. It has now been three years since the last one, and the DTC Verification Task believes another is long overdue. Suggestions for locations included the new NCEP building and the usual NCAR Boulder location. Topics mentioned were hurricane verification, uncertainty quantification and use, and collaborations with data assimilation. In particular, a great number of data assimilation experts reside at NCEP, so it seems that if the workshop were to be held at that location, then data assimilation should be one of the topics.

* 1. *Global modeling (prepared by Bill Kuo)*

With the trend of operational global NWP moving to increased resolution, it won’t be long before operational global models are operated at mesoscale resolution. The traditional boundary between global and regional models becomes murky. Global models being run at mesoscale resolution will face the same challenges of mesoscale modeling, including testing and tuning of physical parameterization at high resolution, optimal use of mesoscale observations, and the verification of high-resolution model forecasts. The work that DTC has been performing related to regional and mesoscale modeling will be relevant to future global NWP.

There were considerable discussions on whether DTC should engage in global modeling. It was concluded that given the limited resources, it is not possible for DTC to take on a major task on global modeling in addition to all the on-going effort, unless new resources are made available. Three possible areas that DTC could participate in global modeling include: (i) testing of scale-aware physics for variable resolution global models, (ii) verification of global models being performed at high-resolution and (iii) conducting workshop in collaboration with operational centers on the planning and development of next-generation global models.

1. **General Discussions**

The DTC Charter states that “*The SAB may elect one of its members as chairperson to facilitate its business*”. The DTC Charter is silent on the term of SAB Chair. SAB met by themselves, and decided to make this a rotating chair, with one year term. Mark Stoelinga serves as the current SAB Chair, and Josh Hacker has been elected as the next Chair.

Overall speaking, the participants felt that this is a more productive meeting (compared with previous SAB meetings). Inviting operational centers to discuss their future plan was well received, as it provided excellent dialog between operational centers and the SAB. This was very helpful in formulating future direction for the DTC. This is something that DTC SAB should continue to do.

The increased role and responsibilities of the DTC task leads in the SAB meeting is very valuable. This allows the discussions to be focused on recommendations that are useful and relevant to the planning of DTC Annual Operational Plan (AOP). As a result, most of the SAB recommendations are actionable.

The DTC will conduct a SAB teleconference meeting in approximately six months. The focus will discuss on how SAB recommendations were incorporated into DTC AOP and the reaction of DTC Management Board and Executive Committee to the SAB recommendations.