ESTABLISHING CLOSER COLLABORATION TO IMPROVE MODEL PHYSICS FOR SHORT-RANGE FORECASTS

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The Developmental Testbed Center (DTC; Bernardet et al. 2008) is a national program that serves as a bridge between research and operations (R&O) by providing a framework and infrastructure for testing promising new numerical weather prediction (NWP) techniques developed by the R&O communities. Ultimately, the DTC will help accelerate improvements in weather forecasts through a facilitated transition of research results into operations. In support of this mission, a workshop organized by the DTC and the National Centers for Environmental Prediction (NCEP)'s Environmental Modeling Center (EMC) engaged participants from academia, various government agencies, and the private sector to find short-term opportunities for improving NWP models and to establish a longer-term framework for closer collaboration between R&O. An emphasis for this particular workshop was placed on short-range, high-resolution prediction and physics issues facing the community.

The first day of the two-and-a-half-day workshop focused on the representation of physics processes in NWP models, including atmospheric radiation, land surface modeling, cloud microphysical processes, the surface and planetary boundary layer (PBL), air–sea interactions, and parameterized subgrid-scale convection. The second day included talks given by representatives from NCEP centers, universities, and private industry, providing their perspectives as key users of model guidance. Presentations were also given by representatives from several National Oceanic and Atmospheric Administration (NOAA)

NWP WORKSHOP ON MODEL PHYSICS WITH AN EMPHASIS ON SHORT-RANGE PREDICTION

WHAT: Experts in short-range numerical weather prediction (NWP) gathered to identify near-term opportunities for making urgently needed physics improvements in the models and to establish a longer-term framework for closer collaboration between research and operations in the development of forecast model physics

WHEN: 26–28 July 2011

WHERE: Camp Springs, Maryland

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labs and from the Naval Research Laboratory (NRL), describing their operational NWP development. The workshop ended with a plenary discussion on identifying a path forward for promoting greater coordination of physics development between the R&O modeling communities.

In summary, the workshop participants recommended the following action items:

- EMC should establish a science advisory board to provide guidance on scientific priorities, with a particular emphasis on physics development.
- EMC and the DTC should work closely to promote R&O collaboration through working group meetings and workshops.
- NOAA's National Weather Service (NWS) should fund a substantial grants program for NWP weather research, including a visiting scientist program that encourages R&O collaboration.
- DTC should establish a mesoscale model evaluation testbed (MMET) with a variety of datasets that can be used by a wide range of users.
- The community developing NWP physics should make greater use of direct physical validation, special observation networks, and simplified modeling frameworks.
- NOAA/NWS should acquire increased computing resources for developing the next-generation high-resolution deterministic and ensemble modeling systems.

Each of these items is described in more detail below. Despite the difficult economic conditions facing our country and the severe pressure it puts on government budgets, the substantial societal and economic benefits of the proposed activities provide compelling reasons to follow the path described in this document.

Since nearly all forecast model products involve physics processes, improving their representation in operational forecast models will lead to better forecasts with far-reaching benefits to society. A few examples of areas that will benefit from forecast improvements include the following:

- Forecasts of the mesoscale environment and the modes of convection that produce severe weather, such as tornados, hail, high winds, lightning, and flash flooding.
- Aviation forecasts in support of the Federal Aviation Administration's Next Generation Air Transportation System (NextGen) program related to in-flight hazards from thunderstorms, clear-air turbulence, and aircraft icing, as well as reduced ceiling and visibility conditions near airports from haze, clouds, and precipitation (including type and intensity).
- Winter storm forecasts of precipitation type and intensity, which can have large impacts on ground and air transportation, paralyzing communities.
- Predictions of wind and solar energy required by the renewable energy industry.

Improved forecasts will also lead to cost savings for utilities and transportation services, better planning for communities and industries affected by poor air quality, and improved watches and warnings for recreational and commercial marine interests.

Although it has been difficult for organizations to work together in developing common dynamical cores for NWP, the sharing and cooperative development of physics packages would be very beneficial to all. Unfortunately, there is no coordinated effort on a national level regarding the development of model physics, including the challenge of developing parameterizations that work over different scales of motions and over a wide range of meteorological conditions. To address this issue, the workshop participants suggested establishing an EMC science advisory board made up of equal representation from universities, operational weather centers, NOAA labs, and private industry. The advisory board would provide feedback to EMC on its current efforts and future plans, and would identify ways to improve communication and collaboration with the wider community. Working groups focused on individual physical processes would be organized under the advisory board. The working groups would collaborate with the DTC to hold regular workshops, establish near-term and longer-term scientific priorities, and foster dynamic interactions between R&O as well as various user communities.

To encourage greater interaction between R&O, a multimillion-dollar NOAA grants program needs to be established to support NWP weather research directed toward improving U.S. weather prediction capabilities. Announcements of opportunity would be sent out to the research community to work on high-priority science challenges facing operational NWP, with funding conditioned on investigators working closely with an operational partner. The program would also support longer-term visits to EMC by scientists and graduate students interested in serious collaboration with scientists at EMC.

A variety of datasets are essential for evaluating the performance of a modeling system. The first stage of testing would be done by researchers, aided by and in consultation with the DTC, which would involve evaluating forecasts made for a set of high-impact benchmark cases or cases from field programs. To enable the first stage of this testing procedure, the MMET would provide datasets that can be used by a diverse set of community users interested in forecasts involving hydrology, severe weather, aviation, energy, ground transportation, air quality, and fire weather. The DTC would solicit input from the R&O communities regarding cases of interest to be included in the MMET. Forecast evaluation results for these cases using select configurations would be established by the DTC and publicized as baselines to the community. The second stage of testing performed by the DTC would be more extensive, involving a series of forecasts with or without data assimilation cycling. A predefined set of verification measures would be used to determine if the new approaches resulted in improved forecast accuracy. If so, the codes would be made available to EMC to be considered for preimplementation testing. An ultimate decision regarding operational implementation would not only take into account forecast performance but computation resources as well.

Forecasts can degrade after adding a more sophisticated physics package because of complex interactions with other physics in a modeling system, or when running with data assimilation cycling because of subtle changes in initial conditions that can build with time. For physics development, it is very helpful to use single-column models, small domain runs, and idealized cases to identify and understand the effects of parameterization changes, as well as variations between different schemes, in a simplified framework with no feedback to the dynamics. Direct physical validation can also be used to compare model forecasts against observations from NOAA Surface Radiation (SURFRAD) sites, the NOAA Hydrometeorology Testbed (HMT) special observation network, Department of Energy Atmospheric Radiation Measurement (DOE ARM) sites, and various field campaigns.[1] These strategies are encouraged as a means of accelerating rigorous physics development.

During the 2011 Hazardous Weather Testbed (HWT) Spring Experiment, forecasters were very encouraged by the guidance provided from high-resolution ensemble systems. These systems are promising because each member is run at convection-allowing horizontal resolutions of 4 km or less, where the complex effects of parameterized convection are reduced. One such system [storm-scale ensemble forecast (SSEF)] was a 50-member ensemble of 4-km forecasts over the contiguous United States using different combinations of models, physics packages, and initialization conditions. The participants suggested using the SSEF datasets to identify systematic differences between individual physics schemes as well as possible physics configurations that can lead to improved high-resolution deterministic forecasts for future high-resolution ensembles.

High-resolution ensembles, as well as many of the complex physics parameterizations being developed by the research community, require substantially greater computing capacity than the current operational system. To meet the ambitious goals of the NWS for Warn-on-Forecast, NextGen, and other high-profile programs, the workshop participants agreed that sufficient computing resources are needed to test advanced, high-resolution deterministic and probabilistic systems, with 4 km being understood as the minimum level of resolution required. The workshop participants noted the availability of a large NOAA computer center (in Fairmont, West Virginia) that could serve as an initial facility for developing these forward-looking NWP systems.

In summary, the participants believe that better coordination between the R&O communities will produce major benefits toward improving model physics, resulting in more accurate and reliable operational NWP forecasts. The open and cooperative attitudes expressed at the meeting, coupled with the obvious potential of the U.S. NWP community to move forward far more rapidly, provided encouragement to the workshop participants that the above steps will lead to profound societal benefits.

As described, future-focused working group meetings and workshops are expected to continue on a regular basis. Presentations and materials from this workshop, as well as a list of attendees, are available at the workshop website (www.dtcenter.org/events/workshops11/mm_phys_11/index.php).

REFERENCES

Bernardet, L., and Coauthors, 2008: The Developmental Testbed Center and its winter forecasting experiment. *Bull. Amer. Meteor. Soc.,* **89,** 611–627.

[1] These methods are useful only when the forecasts are very good and other model errors not involving physics are small.