Enhancements to, and Recent Applications of, the ATEC Data Assimilation and Forecast System

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ABSTRACT

The U.S. Army Test and Evaluation Command (ATEC) Four-Dimensional Weather (4DWX) System includes a mesogamma-scale, model-based meteorological analysis and forecast system that has been deployed at five Army test ranges. The 4DWX modeling system employs a “nudging” (Newtonian relaxation) data assimilation procedure to incorporate a variety of standard and nonstandard observations into analyses of current conditions that are consistent with the model dynamics. These analyses typically are used to initiate forecasts every 3 h, with a typical model configuration providing 24-h forecasts for a nested grid system with a horizontal grid increment of about 1 km on the inner-most grid. This paper discusses recent applications of the 4DWX globally relocatable modeling system and describes recent enhancements to the modeling capabilities.

BACKGROUND

The Four-Dimensional Weather (4DWX) System (Bowers and Shantz, 1997) is a next-generation meteorological support system that was developed by the National Center for Atmospheric Research (NCAR), in collaboration with the Meteorology Division at Dugway Proving Ground (DPG), to enhance meteorological and modeling support capabilities at the major Army test ranges. Major 4DWX components include a common data archival/retrieval system for both internal and external meteorological data sources, a high-resolution mesoscale meteorological model, a variety of user-configurable two- and three-dimensional displays of observational and model data, and linked range applications models (dispersion, noise propagation, etc.).

The 4DWX mesoscale model, the Pennsylvania State University/NCAR Mesoscale Model Version 5 (MM5) (Grell et al., 1994), is now in operational use at five Army test centers: DPG, Dugway, Utah; Aberdeen Test Center (ATC), Aberdeen Proving Ground, Maryland; Cold Regions Test Center (CRTC), Fort Greeley, Alaska; White Sands Missile Range, New Mexico; and Yuma Proving Ground, Arizona. As discussed by Bowers et al. (2002), 4DWX uses MM5 in a real-time four-dimensional data assimilation (FDDA) mode in which Newtonian relaxation is used to nudge the model towards the observations (e.g., see Seaman et al., 1995). These dynamically consisted analyses typically are used to initialize 24-h forecasts every 3 h.
Depending on the Army range, three or four nested computational domains are used with a horizontal grid increment on the inner-most domain of about 1 or 3 km.

As the 4DWX system has continued to evolve, one of the most important enhancements has been the development of a globally-relocatable mesoscale modeling capability to support ATEC developmental and operational tests, including virtual testing (modeling and simulation), at locations other than the five major test ranges. Now known as the 4DWX Global Meteorology on Demand (GMOD) modeling system, a Web-based graphical user interface (GUI) allows operational meteorologists at the Army test ranges to set up and launch MM5 analyses and forecasts for any location in the world. The Linux PC cluster dedicated to GMOD modeling applications also serves as a backup to the range 4DWX modeling systems when there are hardware problems. This paper provides an overview of non-routine uses of 4DWX GMOD technology during the last year and discusses new 4DWX mesoscale modeling capabilities.

RECENT 4DWX APPLICATIONS

The 4DWX system’s GMOD capability was developed to support U.S. Army research, development, test, and evaluation (RDT&E) activities wherever they may occur, not just at the major Army test ranges. However, GMOD technology has been used for other national defense and homeland security applications during FY03.

Operation Iraqi Freedom provided an opportunity to test GMOD capabilities in a data-sparse region that is of considerable interest for national defense. NCAR and DPG set up GMOD to run over Iraq in 4DWX’s Real-Time Four Dimensional Data Assimilation (RT-FDDA) mode, with analyses and 24-h forecasts updated every 3 h. The horizontal grid increments were 30, 10, 3.3, and 1.1 km. Standard GMOD output includes gridded files of meteorological variables in the MEDOC format for input to the SCIPUFF dispersion model, a component of the Defense Threat Reduction Agency’s (DTRA’s) Hazard Prediction and Assessment Capability (HPAC) suite of models. (DPG uses SCIPUFF for operational test support.) GMOD output for Iraq was made available to the National Ground Intelligence Center (NGIC), which uses HPAC for weapons of mass destruction (WMD) consequence assessment.

DTRA has acquired its own 4DWX GMOD capability to support the Agency’s WMD hazard assessments for high profile domestic events such as the 2002 Salt Lake Winter Olympics and the Super Bowl. During Operation Iraqi Freedom, NCAR and DTRA deployed the DTRA GMOD system over the entire continental United States to facilitate emergency response to possible terrorist WMD incidents. The model configuration consisted of a coarse grid with a grid increment of 33 km, and a fine grid with a grid increment of 11 km, with analyses and 20-h forecasts updated every 6 h. Figure 1 illustrates the six overlapping fine-grid output-display tiles used for this homeland security modeling support.

The Joint Urban 2003 Dispersion Experiment, which was conducted in Oklahoma City, Oklahoma in July 2003, was the largest urban dispersion experiment in history with over 150 participants from a number of Government agencies, national laboratories, and universities. Decisions on when to conduct the sulfur hexafluoride (SF$_6$) tracer releases were made 24 h in advance based on forecasts provided by a forecast team from the University of Oklahoma (OU).
As part of its Joint Urban 2003 participation, DPG provided operational GMOD forecasts to the OU forecast team and Joint Urban 2003 experiment director. The model configuration consisted of 5 nested grids (grid increments of 40.5, 13.5, 4.5, 1.5, and 0.5 km) with an analysis and 48-h forecast (12-h forecast for Domains 4 and 5) every 3 h. To improve the high-resolution forecasts over the urban area, NCAR manually revised the urban boundaries to better fit satellite photographs and improved the physics for the urban surface type. The MM5 forecasts did not, however, attempt to account for intra-urban surface variability or buildings. Figure 2 compares an Oklahoma City satellite image with the land-use categories for Domain 4 (1.5-km grid spacing).

The primary purpose of the GMOD runs for Joint Urban 2003 was to support the weather forecasts used for tracer experiment go/no-go decisions. (GMOD’s MM5 forecasts were the only mesoscale model forecasts used by the OU forecast team.) However, NCAR, DPG, and DTRA also collaborated on a demonstration of urban modeling capabilities that soon will be available to HPAC users. MM5 output from GMOD’s Domain 5 was used as input to the Urban Windfield Module (UWM), an Urban HPAC component that will be included in the next HPAC release. UWM was used as a low-resolution computational fluid dynamics (CFD) model, with the buildings in the central business district treated as distributed drag rather than being resolved explicitly. UWM output was then used as input to SCIPUFF, which was executed for a hypothetical SF₆ release using its urban canopy parameterization. (Urban HPAC’s short-range Urban Dispersion Model, which explicitly resolves individual buildings, was not used in this demonstration.) Figure 3 shows an example ground-level dosage (time-integrated concentration) pattern predicted by the linked MM5-UWM-SCIPUFF system.

NEW 4DWX CAPABILITIES

Enhancements to 4DWX modeling capabilities during the last year include (1) improving the GMOD GUI to make the globally-relocatable system easier to use by the nonexpert meteorologist and (2) making the access more portable (via laptop computer or Personal Digital Assistant) to the model control console and products. However, the most significant technical enhancement has been the implementation of an operational ensemble forecast capability in GMOD. Operational ensemble forecasts have been made with synoptic-scale models in recent years to quantify the effects of uncertainties in initial conditions and model physics. However, the computer resources required for mesoscale model forecasts have prevented operational ensemble mesoscale model forecasts until very recently. Using the GMOD 32-node (64-processor) Linux PC cluster, the typical 4DWX ensemble model configuration consists of 3 nested grids (with an approximate 100- by 100-km coverage on the 3-km resolution inner-most grid) with 6- to 8-h forecasts for 16+ ensemble members. The ensemble predictions will facilitate probabilistic forecasts to support test go/no-go decisions (e.g., probability of surface winds exceeding a specified threshold), and output from the ensemble runs will be used as input to applications models. For example, Warner et al. (2002) describe linking an ensemble of MM5 runs with SCIPUFF to predict probabilities of exceeding critical exposure criteria for a hypothetical release of toxic chemicals.
SUMMARY

Work during FY03 on 4DWX enhancement has focused on: (1) developing an operational globally relocatable mesoscale data assimilation and forecast capability to support Army RDT&E activities wherever they may occur, not just at the locations of the major Army test ranges, and (2) developing an operational mesoscale ensemble forecast capability. The ensemble forecast capability will allow meteorologists at the Army ranges to provide their customers with improved decision support products. One important role of the globally relocatable modeling capability is to provide realistic meteorological inputs (“synthetic environments”) to the ATEC/Developmental Test Command (DTC) Virtual Proving Ground (VPG). However, the globally relocatable modeling system has many other potential uses to support Army RDT&E as well as national defense and homeland security.

REFERENCES


Output Sectors