NEW METHODS FOR PROVIDING HIGH-RESOLUTION WEATHER INFORMATION TO WILDFIRE MANAGERS

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1. Introduction

Operational numerical weather forecasts have traditionally been performed using fixed model configurations, where an expert in the use of the particular model, with formal numerical weather prediction training, sets up the model grids and makes many other decisions about model options in configuring the system for a particular geographic area (Warner et al., 2003). This approach has been satisfactory for most operations at national centers such as the U.S. National Weather Service (NWS), because the large coarser-resolution model grids provide coverage for the entire geographic area of responsibility and do not need to be moved. However, with very-high-resolution models, the computational resources need to be focused over relatively small areas, and the small model grids often need to be relocated as the region of interest changes.

One approach to address the need for relocatable high-resolution model grids is to establish “windows” over different geographic areas. This method, employed by the U.S. Air Force Weather Agency and the NWS National Centers for Environmental Prediction (NCEP), is most practical if it is possible to always anticipate future needs, but this is obviously not the case. For example, prediction of high-resolution wind and humidity fields for management of wildfires might require that the highest resolution grid of a modeling system be rapidly relocated on a day-by-day basis as the fire pattern evolves (Seaman et al., 2001).

This paper describes a graphical interface that allows a non-expert user of the Penn State/National Center for Atmospheric Research (PSU/NCAR) Mesoscale Model, Version 5, (MM5) to quickly configure an operational forecast system and launch its operation. This system was used operationally in support of wildfire management efforts in Colorado and Arizona in the summer of 2002. A new attribute of this system is that weather graphics, or output from decision-support systems, can be sent to forward-deployed fire managers through cell phones or personal digital assistants.

The initial motivation for the development of this system by NCAR was to allow U.S. Army Test and Evaluation Command (ATEC) meteorologists, who are not experts in the modeling system, to employ the MM5 model in support of materiel testing worldwide. It became clear during the development of this graphical interface that many other types of applications exist.

2. Description of the meteorological model

The Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) nonhydrostatic mesoscale model, version 5 (MM5; Dudhia 1989, 1993; Grell et al. 1994) is a full-physics, nonhydrostatic, limited-area model. It has many options for parameterization of physical processes such as moist convection and boundary-layer turbulence, and can be used to simulate meteorological processes in any geographic area of the world. However, when the model is set up for a new application, a trained modeler typically needs to make choices about such things as the most-appropriate map projection to employ for the model grids, the physical-process parameterizations that work best for the particular geographic area, and the horizontal and vertical resolutions that will both resolve the atmospheric features of interest and allow a simulation or forecast to be completed in a reasonable period of time.

The version of the MM5 model that has been used for rapid deployment, and for which a graphical user interface has been developed, produces forecasts of typically 12-36 h durations every three hours. The modeling system is comprised of two principle components. One component employs the meteorological model in four-dimensional data assimilation (FDDA) mode, wherein artificial tendency terms are used in the prognostic equations to relax the model state toward observations (Seaman et al. 1995; Stauffer and Seaman 1990;

Stauffer et al. 1991). This FDDA system runs continuously, assimilating surface mesonet data, radiosonde data, satellite-derived cloud-track winds, surface-based profiler data, and Automated Commercial Aircraft Reporting System data.

The model has a grid-nesting capability, which allows the computational resources to be focused over a small geographic area of interest. Within each grid, another finer-resolution grid may be embedded, with the horizontal resolution increasing by a factor of three with each step. The grids "telescope" down in size, as they progressively increase in horizontal resolution, until sufficient resolution is available over the area of interest. For example, if the outer grid has a grid spacing of 30 km, the progressively smaller embedded grids would have grid increments of 10 km, 3.3 km, etc. An example of a typical grid configuration is shown in Fig. 1.

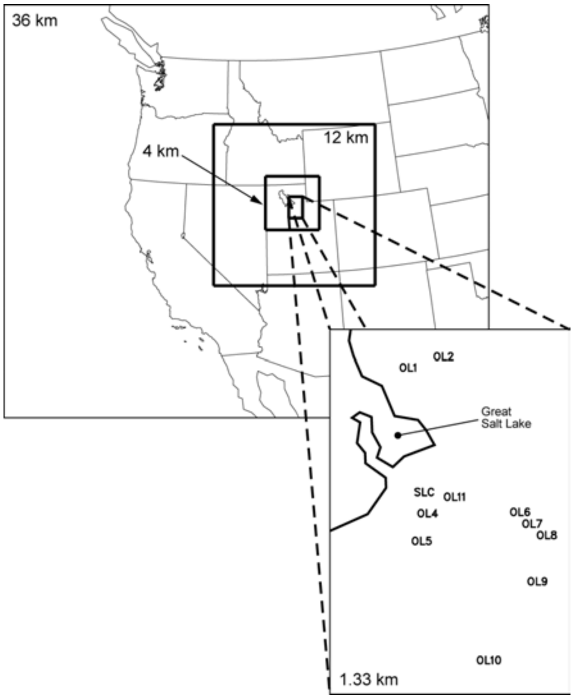


FIG. 1. A typical model grid configuration. In this example, the model was employed for Salt Lake City Olympics counter-terrorism support. The grid increments for each grid are indicated. The expanded inner grid shows the shore of the Great Salt Lake (heavy line), and Olympic event venues (number and letter codes).

3. The graphical user interface to the modeling system

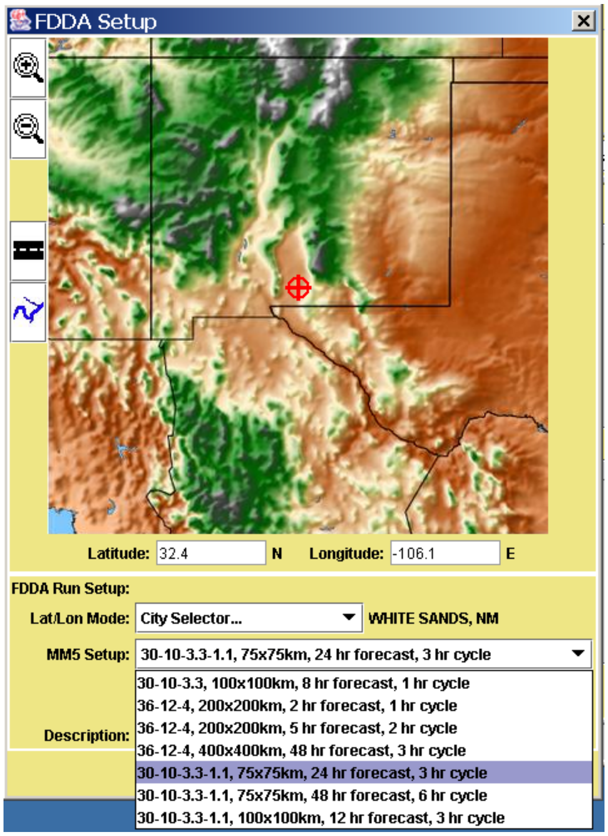
A user accesses model-control system through a World-Wide-Web site. Therefore, the necessary hardware located with the user is a desk-top computer system with hard-wired internet access, a wireless laptop, or personal digital assistant (PDA).

The first step in the model-setup process is to define the region of interest. This can be accomplished by manually entering a grid-center latitude and longitude. A version of the system that runs on a PDA incorporates a portable GPS receiver that can be used to acquire the geographic coordinates, and is especially well suited for users forward deployed in the field. Alternatively, GIS-based navigation tools are available for selecting the geographic area of interest (Fig. 2).


Latitude: 0.0 N Longitude: 0.0 E
FDDA Run Setup:
Lat/Lon Mode: Manual Lat/Lon...
MM5 Setup: ast, 1 hr cycle

FIG. 2. The graphical interface that is used for setting up the geographic area coverage for model forecasts. The user can manually enter a latitude and longitude, or by using GIS-based tools to select the area of interest. The version of the system that runs on a PDA incorporates a portable GPS receiver that can be used to acquire the geographic coordinates.

The next step is to define the model grid configuration and the required forecast duration, which are user definable through the interface. A number of standard grid configurations and forecast lengths have been established from which to begin the process, to minimize the time required (Fig. 3). A more-informed user can enter a grid-corner latitude and longitude, and grid dimensions, or through the mouse with an anchor, drag and click on a map of the global topography and political boundaries. Once the boundaries of a grid are displayed against the background geo-reference fields, the grid position can be fine tuned by dragging it with the mouse. Or, the size and aspect ratio can be adjusted by dragging and clicking corner points. This process is continued sequentially for each grid in the nest.



Latitude: 32.4 N Longitude: -106.1 E

FDDA Run Setup:

Lat/Lon Mode: City Selector... WHITE SANDS, NM

MM5 Setup: 30-10-3.3-1.1, 75x75km, 24 hr forecast, 3 hr cycle

Description:

FIG 3. User specification of the grid horizontal resolution and forecast duration.

Another interface page is used to specify the model physical-process parameterizations to be used on each of the grids. Default options are automatically selected, based on the known geographic and resolution-related limitations of the parameterizations.

After the desired model configuration and forecast duration have been established through the interface, the model can be set up to produce forecasts in either of two configurations. If there is a single event for which a forecast is needed, the system can be configured to produce a single forecast for a particular period, with the data assimilation system allowed to run for a sufficient pre-forecast period so that it is “spun up”. The length of this pre-forecast period may range from 12-48 h, depending on the dominant physical processes. Alternatively, the system can be set up to continuously initiate forecasts every three hours, until a command is given to terminate operations.

When the user launches the model forecast, the instructions are sent to the compute engine through the Internet, the required modeling system is automatically set up, and the forecast is initiated on a Linux PC cluster. At the completion of the forecast, the user is notified through email, pager, or cell phone that the output is available in a specified file on the web site. The user of the forecast then employs a customized Web interface tool to review the model output that is required for decision making.

4. Application of the modeling system to support wildfire management efforts

Anticipation of changes in low-level winds and relative humidity are important to the effective management of wild-land fires, and may be critical to the safety of firefighters. Thus, wildfire managers try to obtain the best meteorological guidance that is available. For guidance about large-scale weather conditions, the operational models of the NWS are sufficient. However, the fact that wildfires often occur in mountainous terrain means that local orographic winds may be as, or more, important than synoptic-scale factors. Thus, higher-resolution models are needed in order to resolve these important local effects. Rapid redeployability is needed because, as the active area of a fire moves, or as new fires develop, the model forecast grid must be moved regularly in order to apply the computational resources where they are needed.

The concept was tested during the summer of 2002, when the forecast system was used by NCAR to support firefighters for two fires in Colorado – The Hayman and Missionary Ridge fires. The fire manager stated that the model output was used directly for planning and tactical operations. Figure 4 shows an example forecast graphic from the model over the Hayman fire.

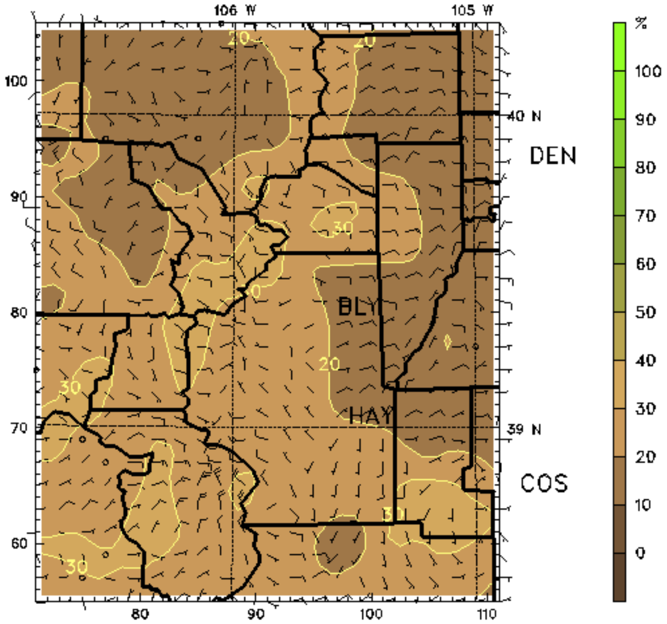


FIG. 4. Example model forecast output over the Hayman fire in Colorado during the operational support of wildfire management efforts in the summer of 2002. Displayed are 10 m AGL winds and near surface relative humidity (shaded). The long wind barb corresponds to 5 m s^{-1}. Relative humidity is contoured with a 10% interval.

5. Summary

Mesoscale models have been used by the research community for thirty years. Because of the knowledge gained from that work and the availability of computing power, such high-resolution local-area models have found many uses in commercial weather forecasting, air-quality forecasting and policy making, military applications, etc. It is our proposition that the next step in this evolution has begun–the use of local-area modeling systems that can be rapidly redeployed by non-experts in the use of the model. An initial application of this sort was described in this paper.

The MM5-based modeling system described here will, in the next couple of years, be replaced by a next-generation system that is based on the Weather Research and Forecast (WRF) community model, being developed jointly by NCAR and the U.S. National Oceanic and Atmospheric Administration.

6. References

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