6.6 REAL-TIME MESOSCALE MODEL FORECASTS FOR FIRE AND SMOKE MANAGEMENT: 2001

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1.0 INTRODUCTION

The Northwest's real-time mesoscale meteorological modeling program is entering its 10th year of operation. Since last reporting at the 2nd and 3rd Symposia on Fire and Forest Meteorology (Ferguson 1998 and 2000), we have made some significant improvements that include:

- Greatly expanded modeling domains,
- Hourly predictions of the Lower Atmospheric Stability Index (LASI or Haines Index: Haines and Sando 1995),
- Hourly predictions of the Fire Weather Index (FWI: Fosberg 1978),
- Linked a new version of NFSpuff (Harrison 1995) for real-time prediction of smoke dispersion in all western states using the outermost grid of the Northwest MM5,
- Implementation of a modeling framework for automating the real-time prediction of cumulative smoke impacts (Ferguson et al. 2001),
- An ensemble forecast to test model results from different input fields and physics options and to help develop estimates of uncertainty,
- Real-time predictions of other environmental components such as ozone, river runoff, and transportation corridor (highways and ferries) conditions,
- Installed the latest MM5 version (3.4),
- Revamped the web page access to graphics,
- Added 4 levels in the boundary layer, and
- Created time-lapse looping functions for all maps.

In addition to physical changes in the modeling environment and output products, more members have joined our supporting consortium, which now includes the USDA Forest Service (Region 6, Pacific Northwest Research Station, and Region 1), Bureau of Land Management, Montana/Idaho Airshed Group, Northwest Fire Coordination Center, Puget Sound Clear Air Agency, University of Washington, Washington State University, Pacific Northwest National Laboratory, Environmental Protection Agency, NOAA National Weather Service, Port of Seattle, Seattle City Light, United States Navy, Washington State Departments of Ecology, Natural Resources, and Transportation, Idaho Department of Environmental Quality, and Oregon State Departments of Ecology and Forestry. Also, corporate affiliates, Sun Microsystems, Inc. and Kuck & Associates, Inc., have made substantial contributions to the effort.

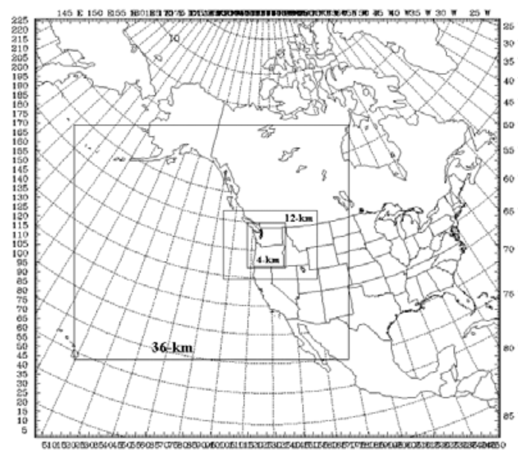

Figure 1. Current configuration of the northwest real-time modeling domains.

The meteorological model is being run and optimized by scientists at the University of Washington under the direction of Prof. Clifford F. Mass with regular input and advice from consortium members. The multi-partner approach has afforded the purchase and regular updates of a high-speed computing system (SUN Microsystems Ultra Enterprise 6500 Server with 30 processors at 20 Gflops each) to generate 60-hour meteorological forecasts at 36, 12, and 4 km horizontal resolution (Figure 1), with 38 vertical sigma levels. The lowest level now is about 19 meters above ground. There are about 5 years of archived data available for case studies. The computing platform is very reliable with negligible downtime.

2.0 THE MM5 MODELING SYSTEM

The numerical weather forecasts are generated by the fifth generation of the National Center for Atmospheric Research (NCAR) and Pennsylvania State University (PSU) Mesoscale Model (MM5) (Grell et al 1994). For a complete discussion of the MM5 modeling system and its development visit the NCAR/PSU MM5 World Wide Web home page at

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<http://www.ucar.edu/ucar/>.
For the Northwest configuration of MM5 visit <http://www.atmos.washington.edu/mm5rt/>.
Currently the model is initialized with the National Centers for Environmental Prediction (NCEP), "early" ETA 221 32-km grids. When these are not available, the Navy NOGAPS model is used for initialization.

The outer grid of 36 km horizontal resolution covers much of western North America and the northeastern Pacific Ocean. A nested grid of 12 km resolution covers the Columbia Basin Airshed (Washington, Oregon, Idaho, western Montana, southern British Columbia, and northern sections of California, Nevada, and Utah). An inner, 4 km resolution grid includes all of Washington and Oregon (Figure 1). The model is run in non-hydrostatic mode in order to limit pressure gradient force errors over the complex terrain. An upper-radiative boundary condition is used to allow gravity waves to radiate through the model top without being reflected. Other parameterizations include:

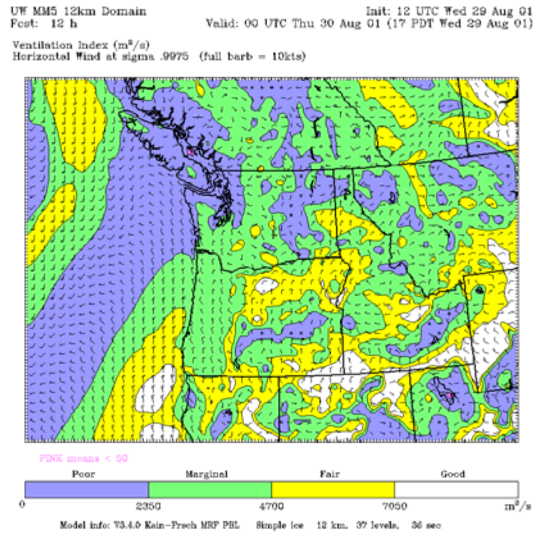
- MRF (or Hong-Pan) planetary boundary layer scheme
- Explicit moisture scheme (including simple ice physics but no mixed phase processes)
- Kain-Fritsch cumulus parameterization on the 12 and 36 km domains

Detailed land use information for each domain was derived from the 1-km USGS digital database, with some subjective modification using other data sources, which were needed to account for such conditions as widespread irrigation in the Columbia plateau region of Eastern Washington.

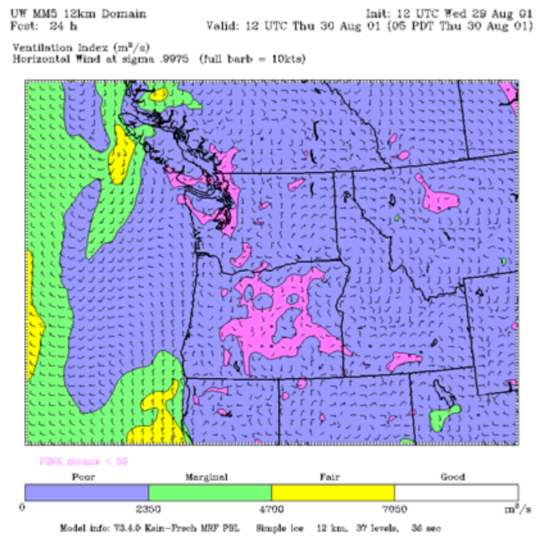
Many of the optimizing features of the northwest MM5 real-time project are the result of case studies during a prescribed fire event, and events that caused particulate matter and ozone concentrations to exceed regulatory thresholds (Ferguson 2000). In addition, continuous verification statistics have illustrated needed improvements; see
< http://www.atmos.washington.edu/mm5rt/verify.html>. As a result, recent efforts have begun to improve the simulation of heavy precipitation, especially in the lee of mountains, and analyze and determine more accurate solutions of the boundary layer that affect the diurnal cycle and surface values of wind, temperature, and relative humidity.

3.0 FIRE AND SMOKE INDEX PREDICTIONS

Two years ago we began calculating a ventilation index (Southern Carolina Forestry Commission 1996). The index is a product of the lowest sigma level wind (19 meters above ground level) and the height of the Planetary Boundary Layer (Troen and Mahrt 1986). Now the index is being used by states to help regulate much of the agricultural burning and some prescribed forest burning. An example of a ventilation prediction for afternoon and morning are shown in Figures 2a and 2b, respectively.



a. Afternoon



b. Morning

Figure 2. Ventilation index calculated from the 12-km MM5; 12 and 24-hour predictions valid for a) 1700 PDT, 29 August 2001 and b) 0500 PDT, 30 August 2001. Areas of poor ventilation are dark shades and good ventilation are light shades.

Several other indexes have proved to be of value to fire weather forecasters and fuel managers. These include the Lower Atmosphere Stability Index (LASI: Haines and Sando 1995) and the Fire Weather Index (FWI: Fosberg 1978). The LASI or Haines Index has been related to extreme fire potential and can be calculated using information at different levels. In the Northwest we calculate the High index (700-500 mb) and Mid index (850-700 mb). An example of the High index is shown in Figure 3.

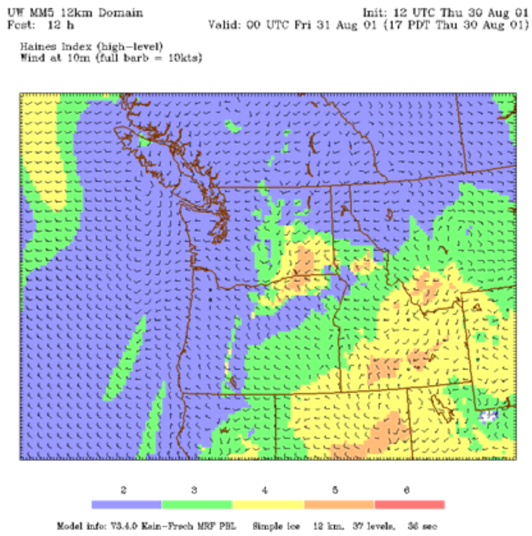


Figure 3. LASI or Haines Index calculated at the High level (700-500mb) from the 12-km MM5 12-hour prediction valid for 1700 PDT, 30 August 2001. Areas of Low danger (2) are dark shades and areas of High danger (6) are light shades.

The Fire Weather Index (FWI) ranges from 0 (low danger) to 100 (high danger). It is derived from the winds, temperature and humidity information in the lowest sigma level (19 meters), using equations that are similar to those in the National Fire Danger Rating System (NFDRS: Deeming et al. 1978). Basically the FWI indicates where it is hot, dry, and windy. In these regions fires will have an easier time consuming

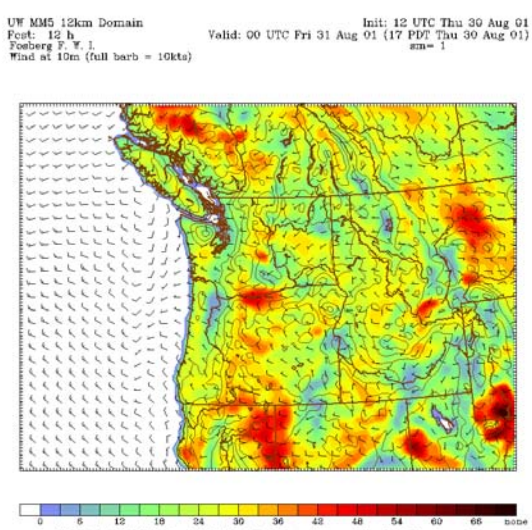


Figure 4. FWI calculated from the 12-km MM5 12-hour predication valid for 1700 PDT, 30 August 2001. Areas of Low danger (0) are light shades and High danger (100) are dark shades.

available fuels. Preliminary studies at the USDA-Forest Service, Pacific Southwest Research Station (Francis Fujioka, *personal communication*) have shown that FWI anomalies are highly coherent and this preliminary calculation of the FWI is useful.

Unfortunately, the National Fire Danger Rating Index (NFDRS: Deeming et al. 1978) and the Canadian Forest Fire Danger Rating System (CFFDRS: Stocks et al. 1989) require some time-lag features and non-weather information (e.g., fuels). Therefore, they are not yet configured for the Northwest MM5 system. CFFDRS is working on the Florida Division of Forestry MM5 prediction system, however, and Florida and the Northwest are working together to implement NFDRS in each domain.

4.0 SMOKE DISPERSION PREDICTIONS

The old 12-km MM5 domain, which encompassed Washington and Oregon was linked to the 2nd version of the smoke dispersion model, NSFpuff (Harrison 1995). NSFpuff is a simple Gaussian-puff model that can be run rapidly on a PC for single or multiple burns. The success of that linkage and expansion of the MM5 domains prompted a new version of NFSpuff, version 3, to be written for the 36-km domain. This allows NFSpuff to be available for all of the western states except Alaska and Hawaii, which are excluded simply because NFSpuff does not contain terrain data for those states. Real-time MM5 data now can be downloaded from an anonymous ftp site and used to project smoke plume trajectories and surface concentrations of particles for 60-hours in advance of ignition.

While NFSpuff is available for users to initialize and run with their own burn data on their own PC's, the Northwest Consortium recognized the need to create cumulative predictions of smoke concentrations from all burners (federal, state, and private) with a more sophisticated modeling tool. Therefore, we began developing an automated smoke-modeling framework (BlueSky) that is described in paper number 6.7 of this volume.

5.0 ENSEMBLE FORECASTS

While ETA and NOGAPS are good synoptic models, they are not always the best available. Therefore, we created an ensemble forecast product that runs MM5 with different initialization packages. Preliminary results of the ensemble system are reported in Grimit and Mass (2001). Figure 5 illustrates different solutions in predictions of precipitation that are possible from each ensemble member. We have found greatest accuracy and thus most confidence in the MM5 prediction when each ensemble solution is close to the mean and have begun exploring the possibility of creating probabilistic predictions based on the ensemble uncertainties.

The ensemble runs additionally provide a method of testing different physics options. By testing different physics options in real-time we have a fast,

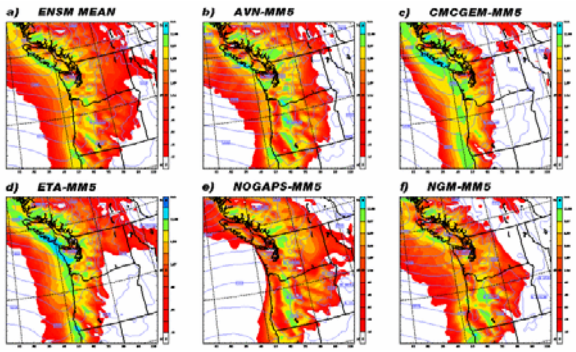


Figure 5. Three-hour accumulated precipitation (dark shades) and sea-level pressure (contours) from MM5 30-hour prediction of the ensemble run initialized at 0000 UTC 13 March 2000 for (a) the ensemble mean, (b) the AVN-MM5, (c) the CMCGEM-MM5, (d) the ETA-MM5, the NOGAPS-MM5, and (f) the NGM-MM5. From Grimit and Mass (2001) with permission.

reliable way of optimizing the MM5 for critical operational needs. We have begun a project to improve simulation of critical variables in the boundary layer and will use the ensemble to test the timing and accuracy of various options before implementing them in the operational model.

6.0 VALUE-ADDED PRODUCTS

All graphical mesoscale weather products are available on the World Wide Web at <*http://atmos.washington.edu/mm5rt*>. Since our last report, we created time-series plots at each sounding location. Time series show predicted trends in surface values ("meteograms") and with height ("time-height profiles"). Meteograms and time-height profiles are generated for 50 selected locations in Washington, Oregon, and southern British Columbia. This year we will add sites for time-series plots in Idaho and western Montana and in the future we plan to create user-selectable sites with "on-the-fly" generation of requested plots. The meteograms (Figure 6) are very useful for illustrating the expected timing of wind shifts, precipitation events, and humidity changes that are critical for prescribed fire planning and wildfire control. The time-height profiles (Figure 7) have proven of value for smoke dispersion estimates and on burns that require air support because they show changes in wind, temperature and relative humidity with height: variables that control the trajectory of plumes and illustrate potentially dangerous wind shears.

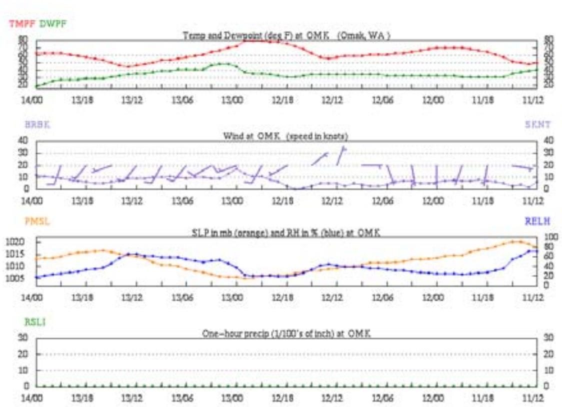


Figure 6. Meteogram of hourly surface predictions from 12-km MM5 for Omak, Washington. Time is displayed from right to left. Temperature (top line) and dewpoint (bottom line) are plotted in top graph, wind speed (line) and direction (barbed line segments) in 2nd graph, sea level pressure (light line) and relative humidity (dark line) in 3rd graph, and one-hour precipitation in bottom graph (none predicted in this time period).

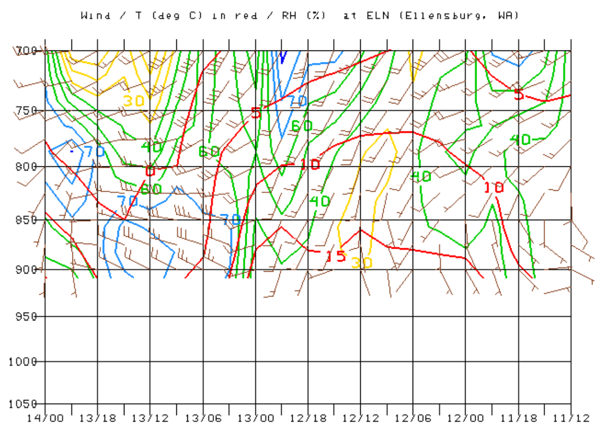


Figure 7. Hourly time-height predictions of wind (barbed line segments), temperature (dark contours), and relative humidity (light contours) from 12-km MM5 for Ellensburg, Washington.

The MM5 model now is fully linked with a distributed hydrological model (Colle et al 1999, Storck et al 1998), which predicts streamflow, and a photochemical model (CalGrid: Yamartino et al. 1992), which predicts surface concentrations of several gas constituents from industrial and areal source emissions. Figure 8 shows the MM5/CalGrid 11-hour prediction of ozone that is valid for 4pm PST 31 August 2001. The model is run on a subset of the 4-km domain. The photochemical model CMAQ, which is part of the EPA Models 3 project, is scheduled to replace CalGrid in the near future. Progress in that direction already has been made.

All mapped products now have time-lapse looping capability from the web site. This feature allows visualization of changing fire regimes or smoke dispersion conditions 60 hours in advance. Finally, we currently are designing an independent web site specifically for fire and smoke weather related products from MM5. As part of this effort we are experimenting with maps showing convective potential and have begun a case study of the 2000 wildfire season to determine MM5 skill in predicting lightning.

7.0 CONCLUSION

All MM5 output products are in color and much easier to understand than the black-and-white representations shown in this paper. Also, while we have shown most examples from the 12-km domain, mapped products from the 36-km domain are useful for viewing the overall synoptic situation and products from the 4km domain provide additional detail in the complex terrain of the northwestern states. We have experimented with MM5 grid fields to 1km and are embarking on an analysis of scale as part of an MM5 case study of the 2000 wildfire season.

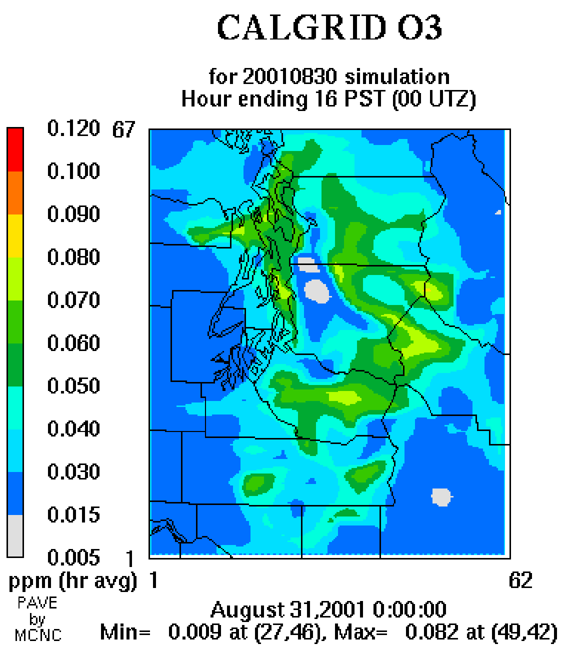


Figure 8. MM5/CalGrid real-time prediction of ozone for the Puget Sound region of Washington State, using a subset of the 4-km domain. The 11th-hour prediction is valid for 1600 PST on 31 August 2001.

The consortium of state and federal agencies in the Northwestern United States has combined resources to bring the tools of very high resolution environmental modeling to fire and smoke managers. The unique combination of resources support both real-time monitoring of air pollution and fire as well as products needed for planning and analysis. Currently the Northwest regional modeling project is the only place in the country where high resolution maps of a ventilation index forecast are available and where smoke dispersion forecasts in regions of complex terrain can be made by local managers with the push of a button.

We have been able to maintain consistent support for research and development, despite the fluctuating budget resources of individual agencies, because of the number of partners in the consortium. When one agency is lacking in funds, another is not.

Although we now have a broad range of interests from consortium members, developing applications that support fire and smoke management remain critical. We expect continuous improvements for years to come.

8.0 ACKNOWLEDGMENTS

This work would not be possible without significant effort from faculty, students, and staff at the University of Washington under the guidance of Prof. Clifford F. Mass. Special thanks to consortium members whose support has maintained the project and whose needs, ideas, and enthusiasm have helped build the Northwest real-time mesoscale modeling project into a valuable operational tool.

9.0 REFERENCES

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