WESTERN REGION TECHNICAL ATTACHMENT
NO. 00-16
DECEMBER 19, 2000

A MESOSCALE MODEL SIMULATION OF A HIGH WIND EVENT IN CENTRAL NEVADA

Mary M. Cairns and Jonathan Corey - WFO Reno, Nevada

[Note: All figures appear only on the Web page at http://www.wrh.noaa.gov/ under Technical Attachments.]

Introduction

Weather prediction in western Nevada is complex due to mesoscale variations induced by the topography. High wind events in western and central Nevada occur with some frequency from early fall through spring. The National Weather Service (NWS) has the responsibility to provide the public with watches and warnings of high wind events. Wind observations are not always available for forecast and verification efforts in the county warning area, and forecasters must depend on local spotter reports, automated observations, and reports from law enforcement officials to aid in the issuance of high wind warnings. Current operational synoptic scale models are, for the most part, unable to resolve the terrain effects. The National Center for Environmental Prediction (NCEP) mesoscale Eta models (i.e., 32-, 28-, 22-, and 10-km versions) are better at resolving effects due to higher resolution, especially with respect to precipitation, but still miss significant details of local wind fields.

The Weather Forecast Office (WFO) in Reno, Nevada, has been running the Pennsylvania State University/National Center for Atmospheric Research Fifth-Generation Mesoscale Model (MM5; Anthes and Warner 1978) to look at various effects of local terrain on higher resolutions, and to evaluate the model predictions. In an early study, Cairns and Corey (1998) found that a 3-km resolution depicted the high wind event which occurred in Reno.

This Technical Attachment (TA) describes a second model simulation of a high wind event which occurred in central Nevada.

Description of the Model

The model used in the study was the non-hydrostatic version of the MM5 (Anthes and Warner 1978, Grell et al. 1993). Three domains over western North America with horizontal resolutions of 27-, 9-, and 3-km were used. The nesting was one-way in the simulation. Twenty-seven half-σ levels (ground to 100-hPa) provided the vertical resolution. The initialization and lateral boundary conditions resulted from NCEP gridded data from the operational Eta model (Black et al. 1993, Black 1994). The model physics package provided options for model simulations: high-resolution planetary boundary layer schemes; an explicit moisture scheme with simplified treatment of ice and snow (Dudhia 1989); an upper radiative boundary condition (Dudhia 1993); and various convective schemes. Other options available were the use of a multi-layer soil temperature scheme, and the use of shallow convection.

The runs were carried out in a non-operational mode on local office equipment. Data from the Eta model were converted from GEMPAK weather analysis software (desJardins et al. 1991) data files to grids acceptable by the MM5 ingest programs. After completion of the model simulation, model output was converted from MM5 grids back to GEMPAK data files for access and display purposes on NAWIPS. Further details about model initialization are described in the next section.

The Event of 3 February 1998

a. Description of the event

Central Nevada experienced a localized high wind event on 3 February 1998. Wind speeds estimated at 87 kt (47 m s^{-1}) occurred in the early morning hours in the central Nevada town of Gabbs, NV (population 300). Mobile homes were moved off their foundations or blown over, a set of bleachers at the local high school were picked up and blown through a fence, and numerous trees uprooted and blown into various structures. A fairly strong eastern Pacific storm was located off the coast of California. The sea level pressure field from the Eta (Fig. 1) show the surface low at 1200 UTC on 3 February. The strongest winds with this event occurred between the hours of 1000-1500 UTC. The 4-km infrared imagery at 1630 UTC from GOES-9 is shown in Fig. 2. Note the wave-like structure in the clouds over central Nevada.

b. Simulation and terrain details

The MM5 for this event was initialized with the 32-km Eta gridded data from 0000 UTC 3 February 1998. The model data is available at the forecast office on an 80-km grid. The first model run from this data (27-km resolution) ran from 0000 UTC 3 February through 0000 UTC 4 February. The 9 km simulation used the 27-km output as the initial data, and ran from 0900-2000 UTC on 3 February. The 3-km simulation ran from 0900-2000 UTC on 3 February. The horizontal resolutions of the grids were 96x101 (27 km), 106x106 (9 km), and 64x64 for the 3-km run. The model simulation for this case consisted of simple ice, the Grell cumulus scheme for the 27-km and 9-km runs (no parameterization was used at 3 km), the high resolution MRF planetary boundary layer scheme (see Hong and Pan 1996 for details) similar to the Blackadar but this scheme saved computation time, and the simple cloud radiation scheme with an upper radiative boundary condition. The physics did include a multi-layer soil temperature scheme, and shallow convection (except at 3 km). We selected these last two options because snow began to fall almost immediately after the high winds ended in this event.

Gabbs is a small mining community located at an elevation of 1414 m at the far east side of the Gabbs Valley along the lower slopes of the Paradise Range. The Paradise Range (over 2621 m) extends from northeast to southeast of town. The east-west Gabbs Valley Range (over 2438 m) is about 29 km southwest of Gabbs (Figs. 3a-b). Figures 4a-c show the 27-km, 9-km, and a close-up of the 3-km terrain for the model simulations. Note the good position and height of the terrain of the Paradise Range with the 3-km terrain.

c. Model results

The terrain around Gabbs and the southeasterly flow initially suggested that the high winds were a result of 'gap winds', that is, acceleration of the winds as a result of tunneling through steep terrain. The surface pressure gradients were generating strong surface winds out ahead of the eastern Pacific trough. Both the Reno and Las Vegas NWS offices had issued wind advisories for central Nevada throughout the night. But, model simulations showed no evidence of these gap winds. Figures 5a-c depict the 0.995 σ-level winds from the 3-km run during the period of high winds, which developed along the western side of the mountain ranges around Gabbs close to 1200 UTC. Note that the strong winds are along the downslope side of the mountain ranges by 1400 UTC. Also, weaker surface winds were evident in the valley to the west, and increased again on the downslope side of the next range in the upper left-hand corner. The winds began to decrease around 1800 UTC.

The previous wind study (Cairns and Corey 1998) showed that strong lee side wind were associated with mountain wave activity. In this case, it was not as evident. The upper-level flow was strong from the southwest which typically produces downslope winds on the east side of mountain ranges. The case in Reno showed well-defined shear lines moving across the valleys under the waves, with strong surface winds developing just behind these lines. The Gabbs simulation showed a short-lived shear line in the Gabbs Valley west of town early on which dissipated by 1500 UTC (not shown). Nothing was evident directly over Gabbs. This lead us to believe that a mountain wave was possibly the cause of the high winds.

To further investigate the relation of mountain waves to the strong winds at Gabbs, we generated several southeast to northwest cross-sections through Gabbs (see Fig. 3 for cross-section A-A' location). Figures 6a-c depict the cross-sections of potential temperature (K) and the circulation vectors (kt). These vectors are the circulation between the horizontal component of the wind orthogonal to the mountain range, and the vertical velocity field. It is assumed that the vertical motion is primarily due to the forcing of the mountains. Both fields indicate the existence of a mountain wave. Gabbs is located at the center of the figure. Time-height diagrams of wind distribution aloft for the Eta and MM5 also depicted the change of wind flow over Gabbs (Figs. 7a-d). Recall that the Eta model was run at a 32-km resolution, while the data displayed is at 80 km (which was available to forecasters in real time). In general, the maximum wind speeds weaken with decreasing resolution. Also, the maximum wind speed occurred at a much higher elevation in the Eta, whereas the strongest winds in the MM5 appeared to have made it close to or at the surface. This difference is also evident looking at a comparison of surface winds from the

Eta and MM5 (Fig. 8). The plotted observed surface winds show that the MM5 simulation is matching the observed winds fairly well. Eta winds were close to the MM5 simulated winds. Though the maximum difference is 10-15 kt (5-7.7 ms^{-1}), the higher concentration of maximum winds and the higher detail could point out a possible high wind situation to a forecaster. This maximum near Gabbs is not as evident in the lower resolution Eta winds field. This case appears unusual because the mountain wave formed and produced winds from the southeast in southwest flow aloft. Typically a forecaster is not looking for evidence of high winds in this type of a configuration.

Summary and Conclusions

The Pennsylvania State University-NCAR Mesoscale Model was used to answer two questions in the simulation of high wind events in western Nevada: Is a higher resolution model able to more accurately predict surface wind events for high wind warnings? And if so, what resolution is required? Limited comparisons were made against current operational NWS models.

The MM5 was successful at capturing the high winds. The event of 29 December 1996 (Cairns and Corey 1998) was more clearly a result of a well-defined mountain wave. The resolution required to accurately predict the high winds around Reno was 3 km. The Gabbs wind storm was more difficult to determine the cause, but after investigation it was determined that it too was a result of a mountain wave oriented in a southeast-northwest direction. The MM5 simulated the high surface winds around Gabbs, in addition to better detail of a mountain wave in the vertical. Again, a resolution of 3 km in the simulations was necessary to depict the areas of high winds, especially compared to the 32-km resolution of the operational model. Both model simulations have indicated that resolutions at or below 5 km might be the most useful to operations for early prediction of high winds in the complex terrain of Nevada. This finding is consistent with other model simulations which produced finer details in wind flow over complex terrain (e.g., Doyle and Shapiro 1996a,b). In an effort to further study these forecast problems, the Reno NWS has begun to run the MM5 in real time. Computer capabilities limit the model resolution to 15 km, but we hope to continue this investigation with the intent to go to higher resolutions.

Acknowledgments. The authors would like to thank Andy Edman, NWS Western Region Scientific Services Division for providing the model code and workstation capabilities for this study. Also, David Bright from the Tucson NWS for his time and efforts in making the MM5 code run on our local workstations, and for his help at setting up the model simulations. Ron Miller provided helpful comments and reviews of this TA. Dr. Robert Rozumalski and Steve Otteson helped provide the figures.

References

Anthes, R. A., and T. T. Warner, 1978: Development of hydrodynamic models suitable for air pollution and other mesometeorological studies. *Mon. Wea. Rev.*, **106**, 1045-1078.

Black, T. L., 1994: The new NMC mesoscale eta model: description and forecast examples. *Wea. Forecasting*, **9**, 265-278.

Black, T. L., D. G. Deaven, and G. DiMego, 1993: The step-mountain eta coordinate model: 80 km 'Early' version and objective verifications. Technical Procedures Bulletin 412, NOAA/NWS, 31 pp. [Available from the National Weather Service, Office of Meteorology, 1325 East-West Highway, Silver Spring, MD 20910.]

Cairns, M. M., and J. Corey, 1998: An application of the MM5 to modeling high winds in complex terrain: A case study in the Eastern Sierra. WR-Technical Attachment, 98-13, 4 pp.

desJardins, M. L., K. F. Brill, and S. S. Schotz, 1991:Use of GEMPAK on UNIX workstations. Proceedings, *7th Int. Conf. On Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology*, New Orleans, LA, Amer. Meteor. Soc., 449-453.

Doyle, J. D., and M. A. Shapiro, 1996a: Mesoscale characteristics of a topographically modulated frontal zone over Norway. Preprints, *7th Conf. on Mesoscale Processes*, Reading, Eng, UK, Amer. Meteor. Soc., 319-321.

Doyle, J. D., and M. A. Shapiro, 1996b: Numerical simulations of severe coastal orographic winds. Preprints, *Conf. on Coastal Oceanic and Atmospheric Prediction*, Atlanta, GA, Amer. Meteor. Soc., 173-180.

Dudhia, J., 1989: Numerical study of convection observed during the Winter Monsoon Experiment using a mesoscale two-dimensional model. *J. Atmos. Sci.*, **46**, 3077-3107.

Dudhia, J., 1993: A nonhydrostatic version of the Penn State-NCAR mesoscale model: Validation tests and simulation of an Atlantic cyclone and cold front. *Mon. Wea. Rev.*, **121**, 1493-1513.

Grell, G. A., J. Dudhia and D. R. Stauffer, 1993: A description of the fifth-generation Penn System/NCAR Mesoscale Model (MM5). NCAR Tech. Note, NCAR/TN-398+1A,107 pp.

Hong, S. -Y., and H.- L. Pan, 1996: Nonlocal boundary layer vertical diffusion in a medium-range forecast model. *Mon. Wea. Rev.*, **124**, 2322-2339.