25.3

APPLICATION OF THE RAPID UPDATE CYCLE AT 10-13 KM – INITIAL TESTING

Stanley G. Benjamin, Tatiana G. Smirnova[1], Kevin Brundage[2], Stephen S. Weygandt, Georg A. Grell[1], John M. Brown, Dezso Devenyi[1], Barry Schwartz, and Tracy Lorraine Smith[2]

NOAA Research - Forecast Systems Laboratory, Boulder, CO

[1]Affiliated with Cooperative Institute for Research in Environmental Sciences, Univ. of Colorado, Boulder, CO
[2]Affiliated with Cooperative Institute for Research in the Atmosphere, Colorado State Univ., Ft. Collins, CO

1. MOTIVATION AND INTRODUCTION

Predictions from the Rapid Update Cycle (RUC) are used heavily as mesoscale guidance for short-range forecasts. Many phenomena important for this application are better predicted with higher spatial resolution, including convection, icing and clouds, turbulence, and surface events influenced by topography and coastlines. In April 2002, the horizontal resolution of the operational RUC changed from 40 km to 20 km (Benjamin et al. 2003a). In anticipation of further planned computer power increases at the National Centers for Environmental Prediction (NCEP), NOAA/FSL has been testing in real time a 10-km regional domain RUC model since early 2001 and started 13-km full CONUS domain RUC model tests in fall 2003. This increase in resolution can produce significant improvements in RUC forecasts of the above phenomena important for aviation, severe weather, and general forecasting. In this paper, we describe the configuration and initial results from the 13-km CONUS RUC and previous results from 10-km RUC model tests.

2. 13-KM RUC CONFIGURATION

The 13-km RUC domain was established with a 50% increase of resolution for each horizontal dimension (13.33.. km to be exact) over the current 20-km resolution. Higher spatial resolution allows more accurate depiction of the actual terrain. Figure 1 depicts the terrain over the northwestern U.S. from the 13-km and 20-km versions of the RUC. Higher elevation is evident in many of the mountainous areas, and the depiction of the Columbia River (Washington and Oregon) and Snake River (Idaho) valleys is also more evident with the 13-km RUC.

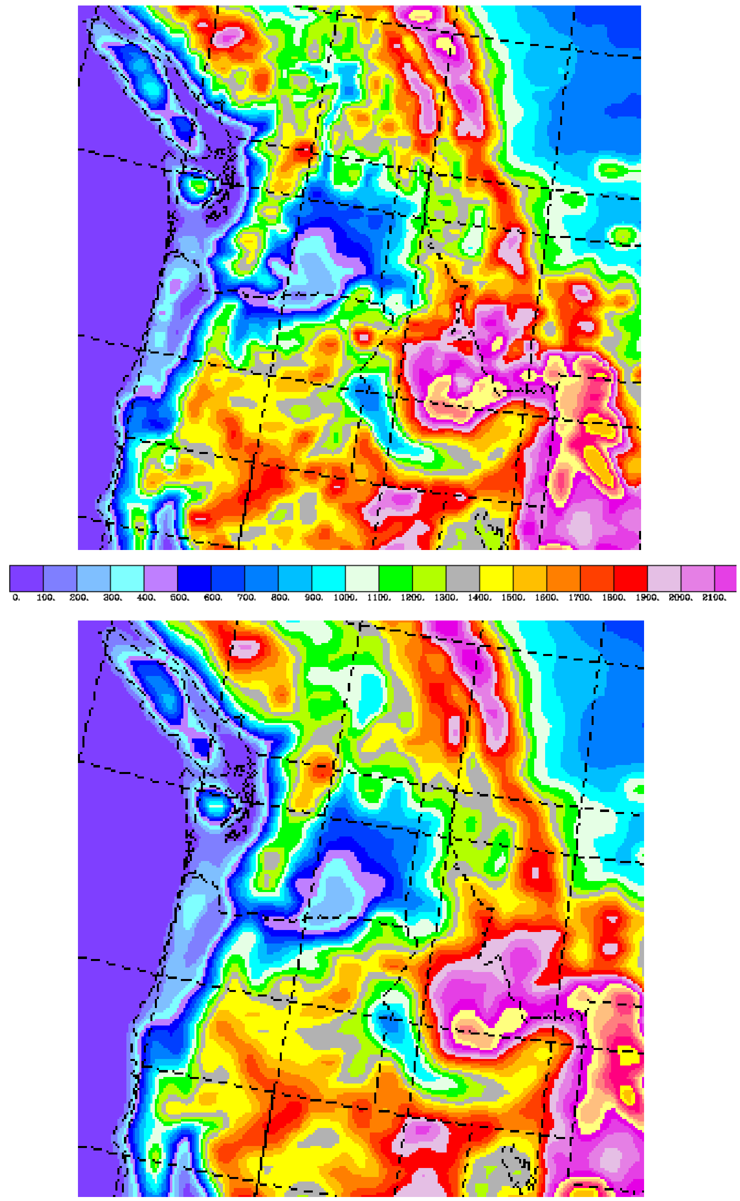

Figure 1. Terrain elevation from 13-km (top) and 20-km (bottom) RUC, extracted for northwest U.S. Contour interval – 100 m.

* *Corresponding author address:* Stan Benjamin, NOAA/FSL, R/FS1, 325 Broadway, Boulder, CO 80305, stan.benjamin@noaa.gov

The 13-km configuration is also better able to depict coastlines and smaller bodies of water. Figure 2 shows that the 13-km RUC reflects the coastline around the Great Lakes more accurately than the 20-km RUC and also is able to capture lakes (e.g., Lake St. Clair between Michigan and Ontario, Lake Champlain between New York and Vermont) and islands not shown in the 20-km RUC land use.

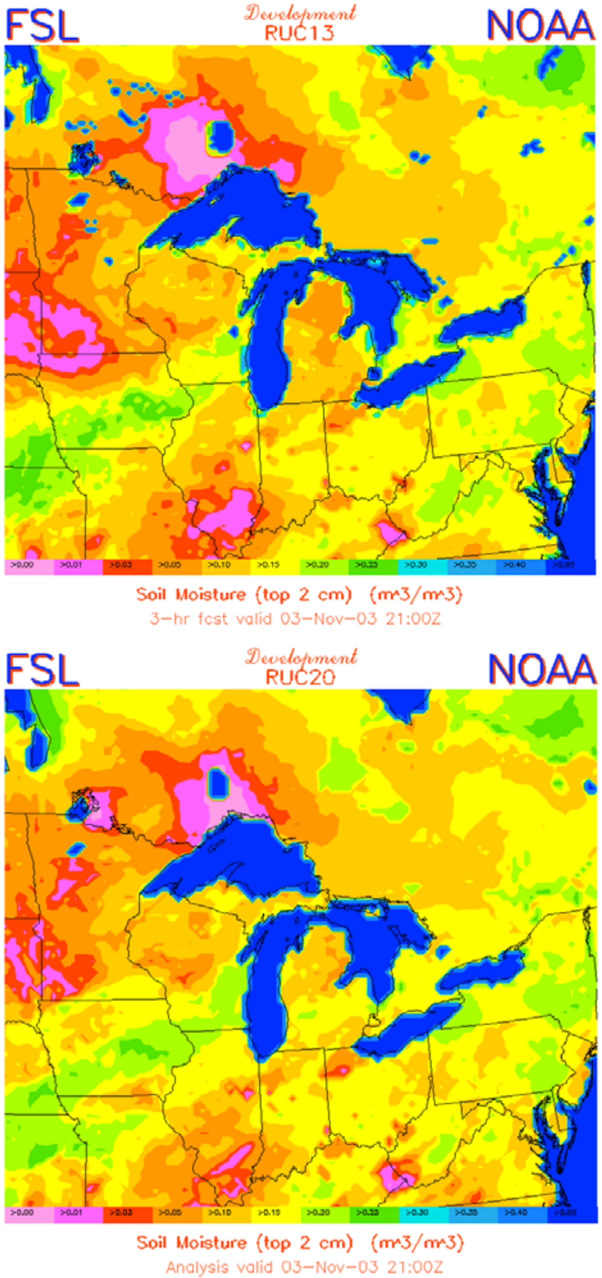

Figure 2. Land-water mask (indicated through soil moisture) with water areas shown in blue from 13-km RUC (top) and 20-km RUC (bottom).

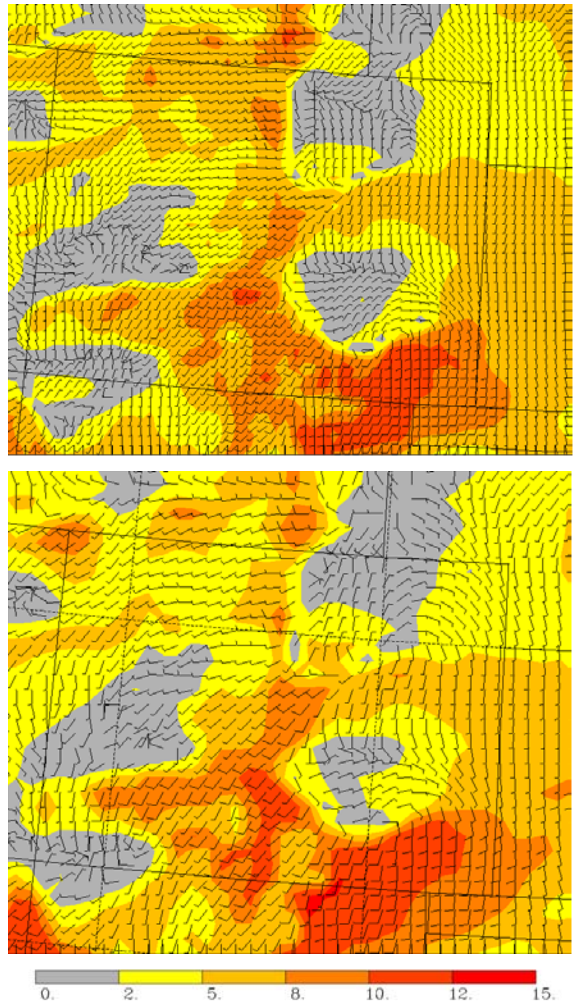

Figure 3. 10-m (sfc) wind 9-h forecasts from 13-km (top) and 20-km (bottom) RUC model, initialized at 1200 UTC 1 Nov 2003. (Units – ms^{-1})

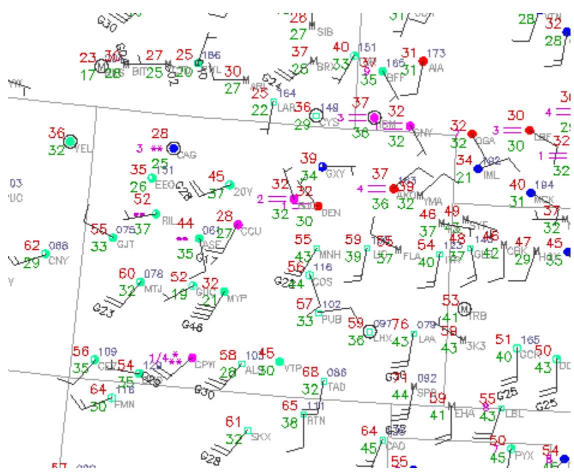

Figure 4. Surface observations valid 2100 UTC - 1 Nov 2003 (Courtesy, NCAR-RAP)

3. 13-KM CONUS RUC FORECASTS

The 13-km full CONUS domain version of the RUC model has been running in real time since fall 2003. At present, initial conditions for these predictions are obtained by interpolation from 20-km RUC native atmospheric fields (including 6 hydrometeor fields) and land-surface fields (assigned to nearest grid points). Initial 13-km testing has been conducted with 50 vertical levels (same as used for the 20-km RUC). Since the 13-km RUC is not yet fully cycling (13-km forecasts being used as the background for 13-km initial conditions), differences between 20-km and 13-km forecasts are generated only via scale interactions during the model forecast. A comparison of 9-h surface wind forecasts at 13-km and 20-km resolution is shown in Fig. 3. In spite of a general southerly flow in the plains east of the mountains, two areas of northerly flow are found in eastern Colorado just east of the mountains, in the South Platte Valley near Denver, north of the Palmer Divide, and in the Arkansas Valley, north of the Raton Divide along the Colorado/New Mexico border. Surface observations at the verifying time of 2100 UTC 1 November 2003 (Fig. 4) show northwesterly flow at Denver (DEN) and Broomfield (BJC). The direction in this area is more accurately reflected in the 13-km RUC forecast than in the 20-km RUC forecast.

4. 10-KM REGIONAL FORECASTS

Since winter 2000-2001, FSL has performed real-time forecasts with projections of 36-48 h using a 10-km version of the RUC model over three different regional domains (Fig. 5). These model predictions were first run for a western U.S. domain in winters 2000-01 and 2001-02 (Weygandt et al. 2002) for the Pacific Landfalling Jets Experiment (PACJET, Ralph et al. 2002), a multiyear project aimed at improving short-term (0-24 h) forecasts of damaging weather along the U.S. West Coast. In spring/summer 2002, 10-km RUC runs were also made for a central U.S. regional domain in association with the International H_2O Project (IHOP). Starting in summer 2002, 10-km RUC forecasts have been run every 6 h for 48-h projections for a regional domain covering the northeastern U.S. and southeastern Canada for the 2002 NOAA Temperature and Air Quality (TAQ) Pilot Project and the 2003 NOAA New England High-Resolution Temperature (NEHRT) Program. Model output has been provided to National Weather Service (NWS) forecasters for display within AWIPS for both the PACJET experiments (to NWS Western Region) and the ongoing 2002-2003 runs (to NWS Eastern and Central Region).

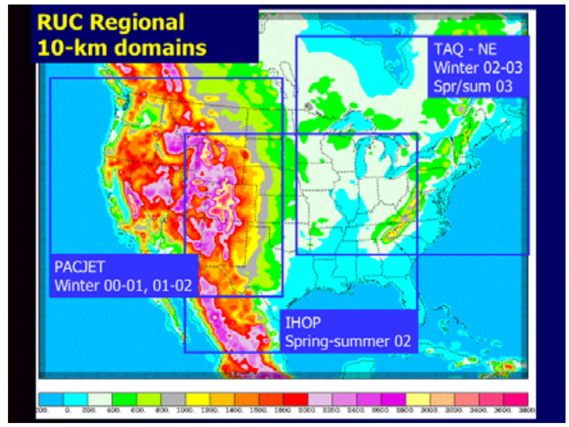

Figure 5. Regional 10-km RUC domains for real-time forecasts out to 36-48 h projections.

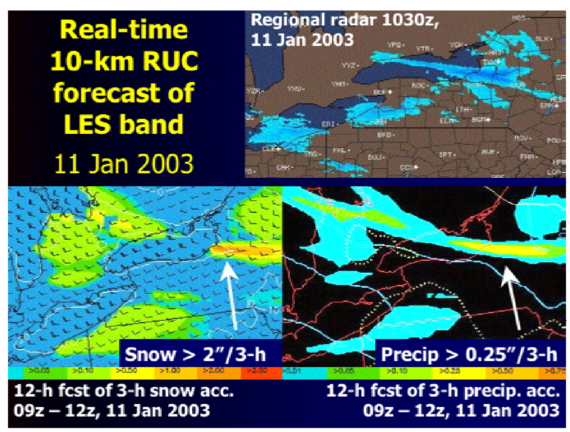

Figure 6. 10-km RUC forecast of lake-effect snow band from 11 Jan 2003.

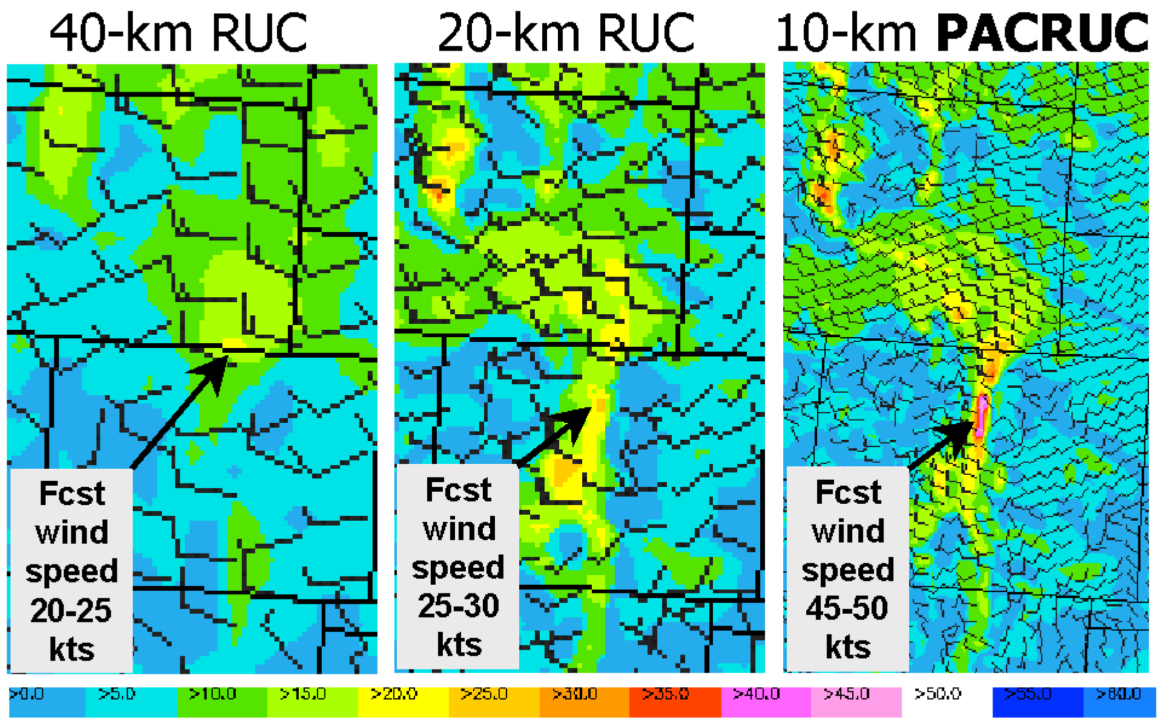

Figure 7. Comparison of (a) operational 40-km RUC, (b) 20-km RUC, and (c) 10-km PACRUC 9-h predicted surface winds (kts) for the Wyoming and Colorado region, valid 1500 UTC 28 March 2002.

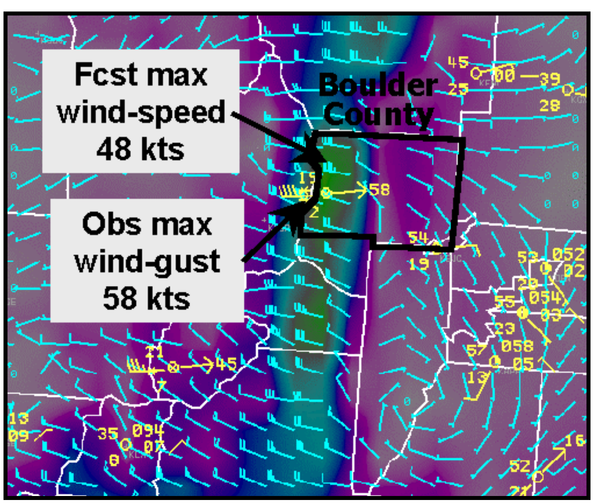

Figure 8. AWIPS display of 10-km PACRUC 9-h predicted winds (kts, wind speed indicated by shading) along the Colorado Front Range, valid 1500 UTC 28 March 2002. Surface observations at forecast valid time are overlaid.

Runs from the 10-km RUC model have been reliable over these different regional realizations in warm and cold seasons, demonstrating the viability of the RUC isentropic/terrain-following coordinate down to 10-km resolution.

We present two examples of forecasts from the regional 10-km RUC model. The higher spatial resolution has been found to be important for improved forecasts of lake-effect snow events to the lee of the Great Lakes. In several cases such as that from 11 Jan 2003 shown in Fig. 6, strong snow bands formed, often with origin/enhancement from more than one of the Great Lakes, with resulting forecasts valid to the county level of accuracy.

Enhanced terrain-related detail is also often seen in the 10-km surface wind forecasts. Figure 7 illustrates the impact of increased horizontal grid resolution (and associated improvements in model terrain) on RUC forecasts of a topographically forced high wind event along the Colorado Front Range. Examination of Fig. 8 indicates that the 10-km RUC forecast reproduced much of the observed county-scale variation in the surface wind speed and direction. In particular, note the agreement between the north-south oriented band of strong westerlies predicted along the crest of the continental divide and the observed 58-kt wind gust on Niwot Ridge in western Boulder County.

A case study comparing 20-km and 10-km RUC forecasts for a 36-h cyclogenesis event from February 2001 is provided in a recent journal paper describing the RUC model by Benjamin et al. (2003b). In this case study, the 10-km RUC model provided a superior forecast of mean sea-level pressure (MSLP) and precipitation, with a 36-h position error of about 50 km for the low-pressure center for an intense East Coast winter storm.

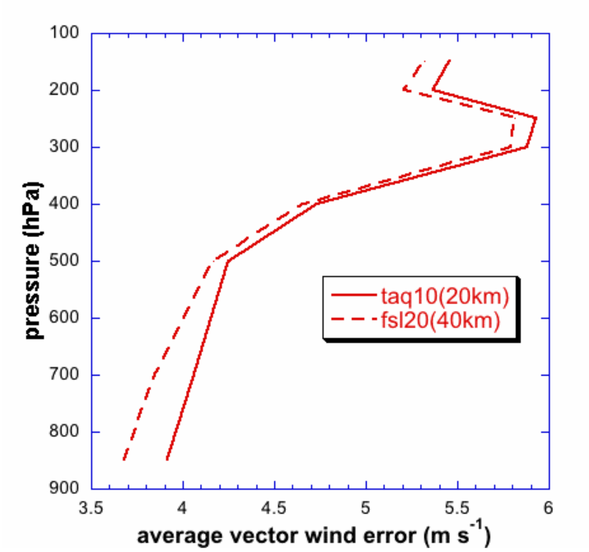

Figure 9. Wind forecast verification for 10-km RUC and 20-km RUC against rawinsondes in northeastern U.S. for October 2003. 10-km regional RUC is verified on 20-km scale and 20-km CONUS RUC is verified on 40-km scale. Units – m/s.

The forecast skill for upper-level winds from the regional 10-km RUC appears to be roughly equivalent to that for the 20-km RUC (Fig. 9). The difference apparent in Fig. 9 is attributable to verification of the 10-km RUC on a 20-km grid and of the 20-km RUC on a 40-km grid, since improved verification scores usually result from use of a coarser-resolution grid for verification. As stated in the introduction, higher resolution is expected to result in improved surface and precipitation forecasts, but not necessarily for point verification above the surface. Therefore, the results in Fig. 9 constitute a reasonable performance for the 10-km RUC.

5. FUTURE WORK

The 13-km RUC tests, now initialized with interpolated 20-km RUC analyses, will be modified to run in a full 13-km cycle by early 2004. This modification will include adaptation of the RUC 3DVAR analysis to a 13-km resolution. It will be considered for possible implementation at NCEP in late 2004 or early 2005. Testing will also be performed for a 13-km version of the WRF model (Benjamin et al. 2002, Koch et al. 2004) over the same full CONUS domain. Currently, implementation of the WRF model into the Rapid Update Cycle, replacing the current RUC hydrostatic model, is planned for late 2006. This version of the RUC with a WRF model component will be known as the Rapid Refresh cycle. Other changes in model parameterizations and data assimilation are expected to accompany the resolution and model changes to the RUC at NCEP.

6. ACKNOWLEDGMENTS

We thank Dr. Steve Koch for a scientific review and Ms. Susan Carsten for an editorial review of this paper.

7. REFERENCES

Benjamin, S.G., D. Devenyi, S.S. Weygandt, K.J. Brundage, J.M. Brown, G.A. Grell, D. Kim, B.E. Schwartz, T.G. Smirnova, T.L. Smith, and G.S. Manikin, 2003a: An hourly assimilation/forecast cycle: The RUC. *Mon. Wea. Rev.* ,**131**, in press.

Benjamin, S.G., G.A. Grell, J.M. Brown, T.G. Smirnova, and R. Bleck, 2003b: Mesoscale weather prediction with the RUC hybrid isentropic / terrain-following coordinate model. *Mon. Wea. Rev.* ,**131**, in press.

Benjamin, S.G., S.S. Weygandt, J. Lee, T.G. Smirnova, G.A. Grell, and B.L. Shaw, 2002: A case study comparison of 10-km WRFRUC and RUC model forecasts from the IHOP experiment. *15th Conf. on Num. Wea. Prediction,* San Antonio, TX, Amer. Meteor. Soc., 275-277.

Koch, S.E., S.G. Benjamin, J.A. McGinley, J.M. Brown, P. Schultz, E.J. Szoke, T.G. Smirnova, B.L. Shaw, D. Birkenheuer, S. Albers, S. Peckham, and G. Grell, 2004: Real-time applications of the WRF model at the Forecast Systems Laboratory. *16th Conf. Num. Wea. Prediction,* Seattle, Amer. Meteor. Soc. (paper 12.1)

Ralph, F. M, 2002: Status report for PACJET-2002 field activities. http://www.etl.noaa.gov/programs/2002/pacjet

Weygandt, S.S., S.G. Benjamin, C.S. Velden, J.E. Burks, and L.B. Nance, 2002: High-resolution RUC forecasts for PACJET: Real-time NWS guidance and retrospective data impact tests. *15th Conf. on Numerical Weather Prediction,* San Antonio, TX, Amer. Meteor. Soc., 300-303.