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Visibility Forecasts from the RUC20

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1. Introduction

At least five characteristics of the new 20-km Rapid Update Cycle (RUC20, Benjamin et al. 2002a, this volume), being implemented at NCEP in April 2002, should contribute to improvements in visibility forecasts. These include higher horizontal and vertical resolution (from 40 km to 20 km, 40 to 50 levels), improved versions of the MM5/RUC mixed-phase cloud microphysics and RUC land-surface schemes, assimilation of GOES cloud information modifying RUC 1-h hydrometeor forecasts (Benjamin et al. 2002b), and an improved RUC visibility algorithm (Smirnova et al. 2000), which was originally based on the Stoelinga-Warner method. Ongoing 3-h verification against METAR visibility observations is being conducted for forecasts from both the RUC2 (called RUC40 in this paper) and the RUC20 to assess the impact of the changes. Results from these statistics indicate improvement in daytime forecasts using the RUC20. Case studies of particular interest to the aviation community will also be investigated and discussed.

2. The Rapid Update Cycle

The Rapid Update Cycle (RUC) is a numerical weather prediction system used over the lower 48 United States and adjacent areas of Canada and Mexico. It features a very high-frequency cycle with mesoscale data assimilation and forecast model components. Since 1998, the RUC has run with a 1-h update cycle at the US National Centers for Environmental Prediction (NCEP) with forecasts out to 3 h produced hourly, and forecasts out to 12 h produced every 3 h. Each hourly analysis in the RUC uses the previous 1-h forecast as a background, and recent data are used to calculate an analysis increment field which modifies the background. The data cut-off time for the RUC is very short, only +20 min for observations valid at the analysis time or over the previous one hour. The grid length is 40-km, with 40 hybrid isentropic-sigma levels (RUC40, Benjamin et al. 1999).

Since late 2000, FSL has been testing a 20-km 50-level version (RUC20) with further improvements in analysis and model techniques (Benjamin et al. 2002). The RUC20 is scheduled for operational implementation at NCEP in April 2002. The primary model changes in the RUC20 include a new Grell convective parameterization, explicit clouds using mixed phase microphysics, an update to the RUC/MM5 Reisner level-4 mixed-phase microphysics developed jointly by NCAR and FSL, and new land-surface processes. RUC20 also assimilates GOES cloud-top data to assist in the description of initial cloud/hydrometeor fields. The smaller grid size also allows the RUC20 to resolve smaller areas of clouds and precipitation, which should benefit visibility diagnoses. A more accurate diurnal cycle with a more frequent call to the shortwave radiation module should also make a minor contribution toward diagnosis of fog/low-level clouds.

The visibility field from the RUC is output from a visibility translation algorithm that uses near-surface hydrometeor (cloud water, rain water, snow, ice, graupel) mixing ratios and relative humidity as input. This algorithm is described in more detail by Smirnova et al. (2000). There is potential for significant error in any visibility diagnostic using model output due to local variations in atmospheric aerosols (both natural and anthropogenic), not to mention approximations in the forward model used to obtain visibility from the forecast model output. The use of relative humidity in the diagnostic is necessary to improve mean performance, but it is a crude approximation. In fact, visibility can vary greatly for a given relative humidity.

3. Visibility comparison of RUC20 / RUC40

Verification of the visibility diagnostic from analyses and forecasts from both RUC20 and RUC40 is done every 3 h against METAR observations. To accentuate visibility differences at lower visibility, the verification is of the *natural logarithm of visibility in km.* The visibility verification scores are calculated both for RMS observation-forecast difference and bias (mean difference).

Table 1 shows the RMS values averaged over 10 days (15 Feb 2002 – 25 Feb 2002) at 0000, 0300, 0600, 0900, 1200, 1500, 1800, and 2100 UTC to track the daily pattern of the visibility forecasts. The comparison over the full U.S. shows a definite diurnal pattern of better RUC20 forecasts during the day, while the RUC40 was better overnight. Table 1 also shows the RMS averages for the eastern U. S. only. The RUC40 numbers are nearly identical with the numbers for the entire country, but RUC20 shows better results in the eastern US than in the western US. An investigation will be made about the cause of poorer RUC20 performance in the western US.

Table 1. RMS of observation-analysis difference of natural logarithm of visibility. Analysis is using RUC visibility diagnostic algorithm

	00	03	06	09	12	15	18	21
20	.82	.79	.97	1.08	1.13	1.03	.79	.82
40	.97	.80	.76	.78	.77	.85	.96	1.06
20E	.80	.75	.90	.92	.98	.84	.72	.81
40E	.98	.80	.76	.79	.77	.85	.96	1.06

The bias is closer to zero (better) for the RUC20 at most times of the day, except for 0900 and 1200 UTC, which were the best times for the RUC40. RUC40 biases are consistently negative (visibility too high), while the RUC20 is negatively biased during the day (visibility too high), and positively at night (visibility too low, presumably due to the relative humidity effect in the RUC visibility translation algorithm).

Table 2. Bias of observation-analysis difference of natural logarithm of visibility.

	00	03	06	09	12	15	18	21
20	-.37	-.17	.09	.22	.31	.12	-.28	-.42
40	-.54	-.30	-.15	-.09	-.03	-.23	-.52	-.74

4. RUC20 case studies

FSL has rerun two cases (27 Nov 2000 and 21 Jan 2001) for southern California and the northeastern U. S. using the 20-km RUC. These cases were selected by collaborators at NCAR (National Center for Atmospheric Research) as being of special interest to the aviation community. A suite of output fields for both cases has been placed on the web for viewing under http://ruc.fsl.noaa.gov. Click on "Ceiling and Visibility Study" from the index on the left, and then the date and area of interest can be chosen under this menu. It will automatically come up with the “NorthEast” case for 21 Jan 01, but you can change the date to 27 Nov 00, and the area to the “SouthWest” to look at the California case in detail.

For the southern California case, low marine stratus and fog were observed along the coast, causing problems at Los Angeles International Airport (LAX). The RUC20 model forecasts do moisten the atmosphere and lower the diagnosed visibility below 8 km (5 miles) using the RUC visibility algorithm (further refined for the new RUC20 version) over the 12 h forecast, but do not saturate to produce fog or low stratus (Fig. 1). In the wind field, the RUC20 model does create a Catalina eddy in the California bight (Fig. 2). Although the model failed to explicitly predict the observed low ceiling and visibility near the coast, the appearance of a Catalina eddy in the forecast would have alerted forecasters that impact on aircraft operations was likely. The Tule fog in the Central Valley of California was nicely captured as well. Several fields are available to view on the web from the analysis, and 1, 2, 3, 6, 9, and 12-h forecasts from 0000 UTC 27 Nov 00.

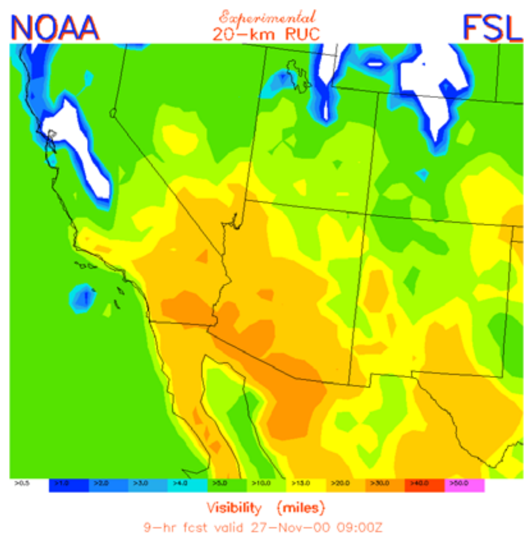

Figure 1. 9-h forecast of visibility from the RUC20 valid at 0900 UTC 27 Nov 00. Forecast visibility in the LA area is between 4 and 5 miles.

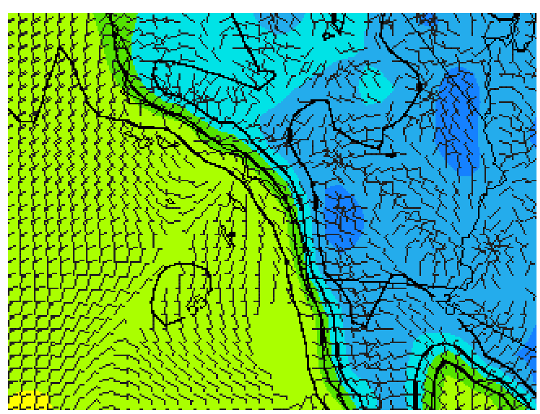

Figure 2. 9-h forecast of surface wind (barbs) and dewpoint from the RUC20 valid at 0900 UTC 27 Nov 00 over southern California.

The Northeast case (12-h forecast from 0000 UTC 21 Jan 2001) features a large extratropical cyclone creating IFR conditions over New York City (NYC) and southern New England. The

RUC20 model did a better job of capturing the intensity of the weather in this more strongly forced situation compared to the California case. The New York metro area, along with large parts of the Northeast, stay socked in with diagnosed visibilities under 0.8 km (0.5 mile) for most of the forecasts (Fig. 3). The RUC20 model also forecast low clouds (Fig 4.) and mixed precipitation (Fig. 5) in the region. However, NYC stays mostly in the snow in the RUC20 forecast, with the rain/mixed precipitation line coming closest to NYC in the 6-h forecast. The fields available on the web are the analysis, and 1, 2, 3, 6, 9, and 12-h forecasts from 00 UTC 21 January 01.

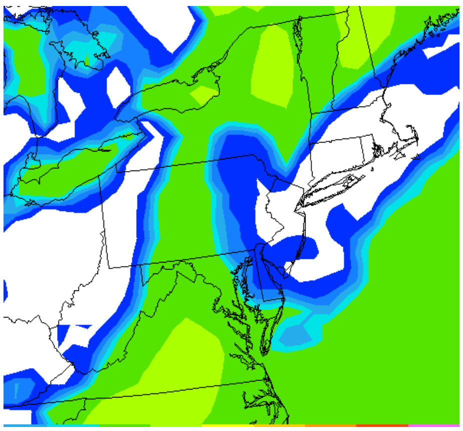

Figure 3. 12-h forecast of visibility from the RUC20 valid at 1200 UTC 21 Jan 01. White denotes visibility less than 0.8 km.

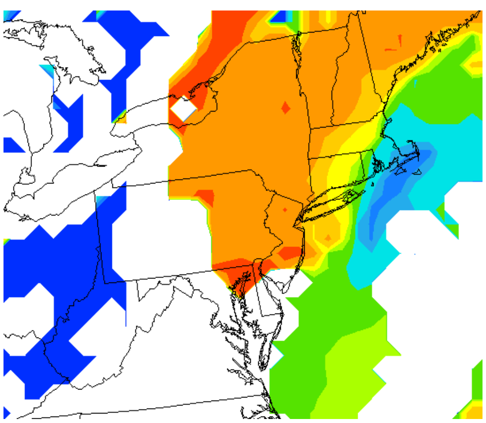

Figure 4. 12h forecast of cloud base height from the RUC20 valid at 1200 UTC 21 Jan 01. Ceilings in the NYC area are below 5000 ft, with lower ceilings off to the east.

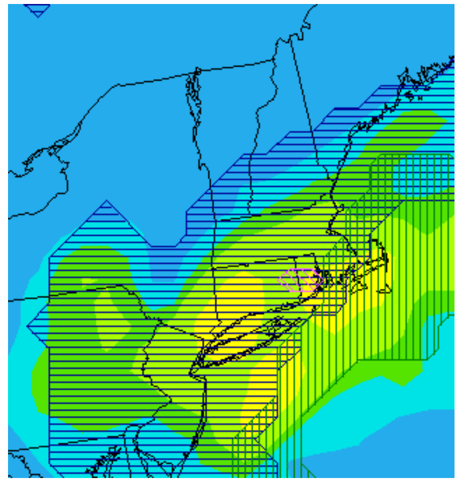

Figure 5. 12-h forecast of precipitation 3h accumulation and type valid at 1200 UTC 21 Jan 01. Horizontal lines are snow, vertical lines are rain, crosshatching is mixed precipitation, a small area of sleet is shown over Rhode Island. The lightest grey shading indicates areas of 3-h precipitation amounts between 6 mm and 12 mm (.25-.5 in.)

Our final case is from 1200 UTC 30 Jan 02 over the southeastern United States and compares RUC40 and RUC20 analyses with observations. Figure 6 shows the visibility analysis from the RUC40 and Fig. 7 shows the same thing for the RUC20. There is a clear difference in the analysis over South Carolina, Georgia, and Alabama. In the RUC40, the visibilities are diagnosed as greater than 8 km (5 mi.), while the RUC20 is showing much reduced visibilities of less than 1.6 km (1 mi.). Actual observations of visibility are shown in Fig. 8. Observations in the region of interest agree much better with the RUC20, with the majority at 0 or 1 mile.

5. Conclusions

Improvements in the RUC20 over the RUC40, notably assimilation of cloud fields from GOES and updated microphysics, have led to improved ceiling and visibility forecasts as shown by several case studies. Limited verification statistics indicate the RUC20 is doing better forecasting visibility bias-wise except during the late night hours. Indications from studies with other models suggest that improved explicit prediction of West Coast low stratus and fog may require use of a more detailed long-wave radiation scheme (Dave Stauffer, 2001, personal communication).

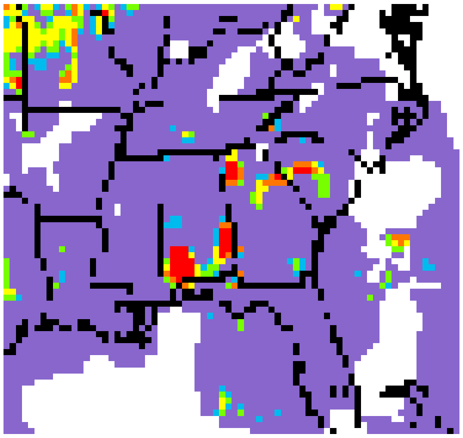

Figure 6. Analysis of visibility from RUC40 at 1200 UTC 30 Jan 02. Lighter regions have greater visibility, with white being unlimited.

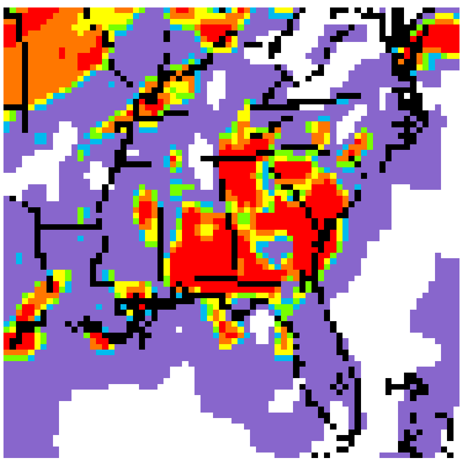

Figure 7. Analysis of visibility from RUC20 at 1200 UTC 30 Jan 02. Lighter regions have greater visibility, with white being unlimited.

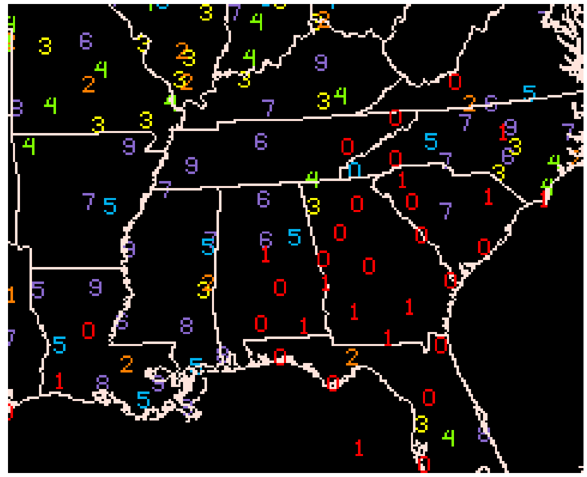

Figure 8. Observations of visibility in miles from 1200 UTC 30 Jan 02.

6. Acknowledgments

We thank Geoff Manikin at NCEP for the use of the figures from the 30 Jan 02 case.

7. References

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