8.7 AN INITIAL RUC CLOUD ANALYSIS ASSIMILATING GOES CLOUD-TOP DATA

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1. INTRODUCTION

FSL has been running a parallel test Rapid Update Cycle (RUC) with assimilation of GOES sounder cloud-top data alongside a control cycle without this cloud analysis since April 1999. The cloud-top data used in the experiment are derived from the GOES sounder measurements available hourly from NESDIS/CIMSS in Madison, Wisconsin (Menzel et al. 1998). The results of parallel run forecasts at 1, 3, 6, 9, and 12-h projections are routinely compared with those of the control run. Cloud forecasts from the two cycles are verified against the GOES cloud product, and primary variables such as temperature, winds, and relative humidity are verified against rawinsonde profiles at synoptic times. Since the last report of intermediate results (Kim and Benjamin, 2000), we observed over-building of clouds during winter time. Therefore, we revised the cloud analysis method to reduce moistening in cloudy grid columns.

The GOES sounder cloud product has been very useful for improving hydrometeor prediction, but it has been necessary to recognize its limitations. When the primary algorithm for the cloud product using sounder measurements (CO_2 slicing method) fails, the window channel method is used. In this case, the cloud-top pressure will strongly depend on the guess profile. An improved GOES cloud-top product should be available soon (personal communication, Schreiner, 2000).

2. MODIFICATIONS

The modifications made in this version of the RUC cloud analysis are to avoid over-building of clouds by a more conservative application of the cloud-top data. First, we selected the higher cloud-top data if the variance provided with the GOES cloud-top product was larger than 100 hPa. This accounts for underestimation of cloud-top due to an emissivity less than one. Second, the horizontal assignment of GOES values to RUC grid points was made also made more conservative by using a narrower window, now only within the RUC grid box with an overlap of 10 km. Third, any cloud-top pressure value greater than 650 hPa is now not used in cloud building. An example of problems in the current product with a cloud-top assignment in a stable lower troposphere is often evident in marine stratus off the California coast. Cloud building still takes effect only when the effective cloud fraction is larger than 0.8, but now the cloud water added is smaller, no more than half of the cloud-water to rain autoconversion threshold value (10^{-4} g kg^{-1}). The cloud thickness remains the same as 50 hPa.

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3. RESULTS

The predicted cloud-top pressures are compared with GOES sounder-derived cloud-top data where available for five forecast projections (1, 3, 6, 9, 12-h). The predicted cloud-top pressures are estimated using a hydrometeor mixing ratio threshold value of hydrometeors (10^{-8} g g^{-1}). Statistical verification measures including bias, standard deviation, correlation coefficient of cloud-top pressures, and lagged auto-correlation coefficients are computed every three hours.

The correlation coefficient verification in Fig. 1 (parallel run with revised cloud analysis) and Fig. 2 (control run - no cloud assimilation) for the period of 13-17 June 2000 shows an improvement similar to earlier test periods (e.g., Kim and Benjamin 2000). This figure shows slightly reduced correlation coefficient values, compared to earlier tests, from the more conservative analysis in the revised version. The impact of cloud assimilation decreases with forecast duration, as expected, but some improvement is still apparent even in most 12-h forecasts. This pattern is typical of other test periods. As also evident in other test periods, both cycles show a diurnal cycle in accuracy of cloud-top forecasts, with a minimum in late afternoon (when convective activity is strongest) and a maximum at nighttime. To answer the question of the effectiveness of the cloud assimilation raised in the previous report (Kim and Benjamin 2000), we also compared statistics with lagged auto-correlation coefficients for the same period (Fig. 3). This lagged correlation coefficients show a similar pattern of diurnal cycle suggesting that diurnal pattern is not caused by cloud analysis method.

Verification of 3-h RUC relative humidity forecasts against rawinsonde is shown in the bottom of Figs. 4 and 5. The forecasts are initialized at 0900 and 2100 UTC for 3-h forecast valid at 1200 and 0000 UTC and verified during 22 through 29 June 2000. The RH statistics (bias and standard deviation of forecast-minus-rawinsonde value) generally show a positive impact from the cloud-top assimilation on relative humidity. This positive impact is strongest for the 300-500 hPa levels and weaker below, perhaps due to the decision to not build clouds below 650 hPa.

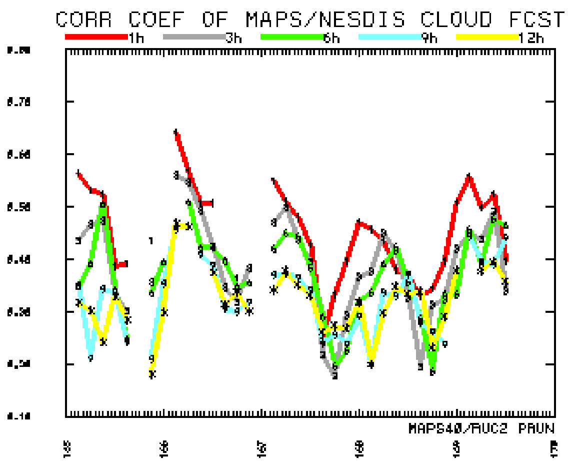

Figure 1. Time-series of correlation coefficients of predicted cloud-top pressures from parallel run with cloud analyses and GOES-derived values. The statistics every 3 h show predictions of 1, 3, 6, 9, and 12 h for initial times starting at 0000 UTC 13 June 2000 (Julian day 165)

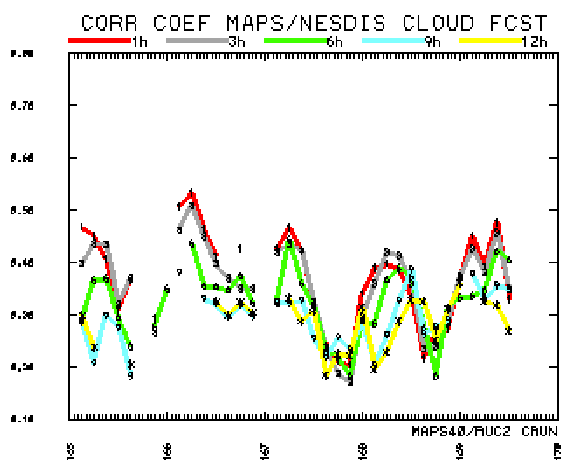

Fig. 2 The same as Fig.1 except for control run forecasts.

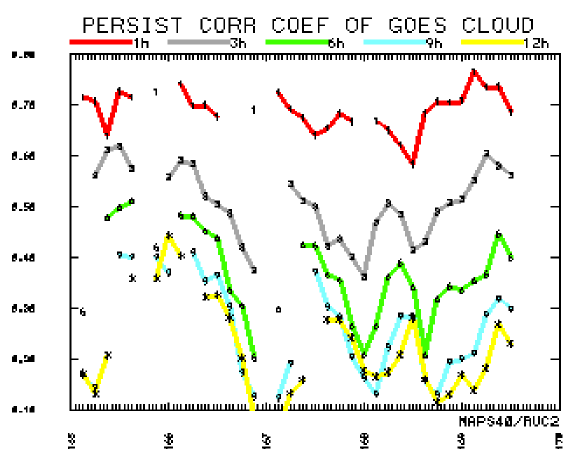

Figure 3. Time-series of lagged (1,3,6,9,12-h) auto-correlation coefficients of GOES cloud-top pressures.

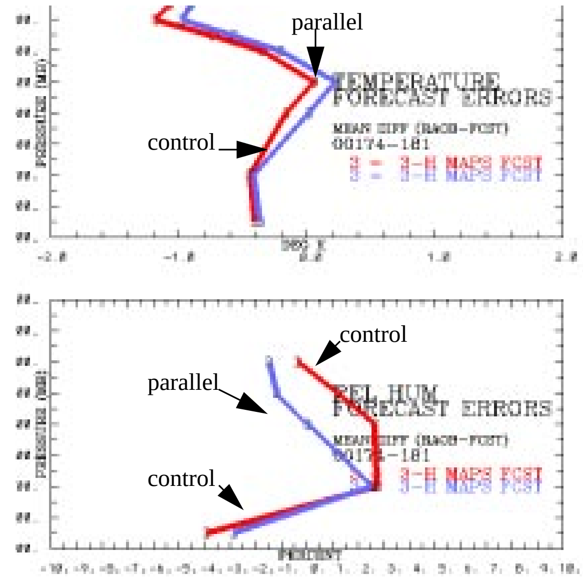

Fig. 4 Comparison of 3-h RUC temperature and RH forecast mean difference (bias) verified against rawinsonde observations for 22-29 June 2000. Results are shown for the control run (no cloud assimilation - red) and the parallel run (with cloud assimilation - blue).

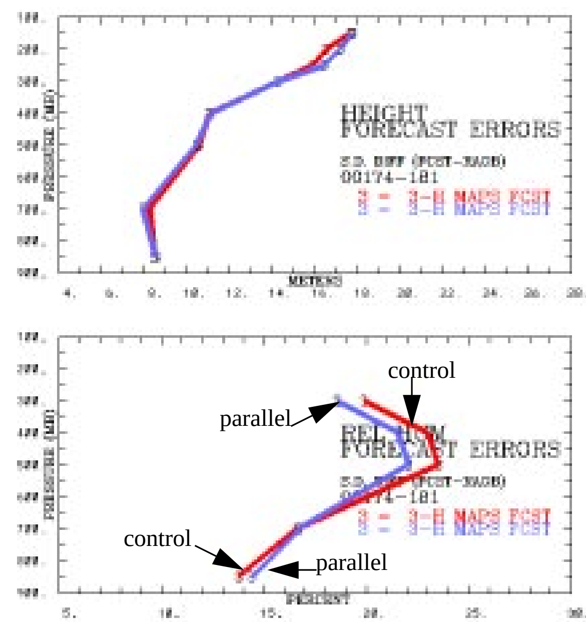

Fig. 5 Comparison of 3-h RUC height and RH forecast error standard deviation verified against rawinsonde observations for 22-29 June 2000. Results are shown for the control run (no cloud assimilation - red) and the parallel run (with cloud assimilation - blue).

4. GOES IMAGER DATA FOR RUC

FSL has also continued research on generating an hourly cloud product based on the GOES window channel imager data that appears to have some advantages over the current sounder-only product. By utilizing full-resolution (4 km) pixel data for each RUC grid box, this imager-based cloud product includes multilevels within each grid box. An adaptive classification (Kim and Nychka, 1998) is applied to the imager data to determine the number of distinct radiating layers, namely cloud layers and possibly the surface, and fractional coverage and brightness temperatures of the respective layers. Then, cloud-top pressures are estimated for the brightness temperatures of each of these cloud layers through passing first-guess profiles from the RUC forecast to a radiative transfer (forward) model (obtained from CIMSS). This imager-based cloud product thus provides extra multilevel cloud and cloud fraction data to complement sounder data. No data impact experiments have yet been performed with this product, but they are planned.

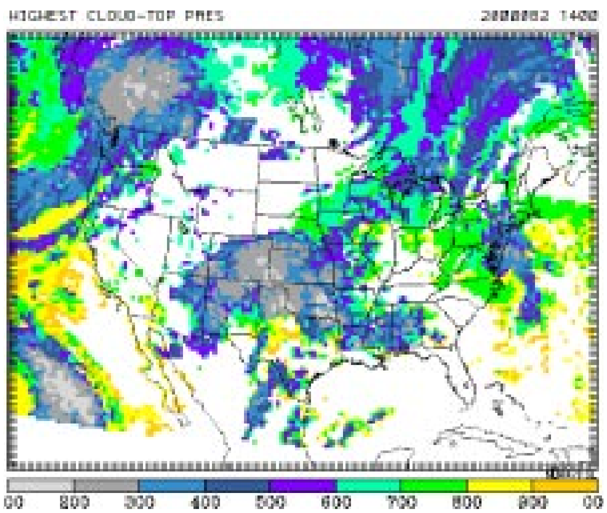

Figure 6. Cloud-top pressure derived from GOES-8/10 full resolution imager data. The highest cloud-top is displayed if there are multiple cloud levels in a grid box.

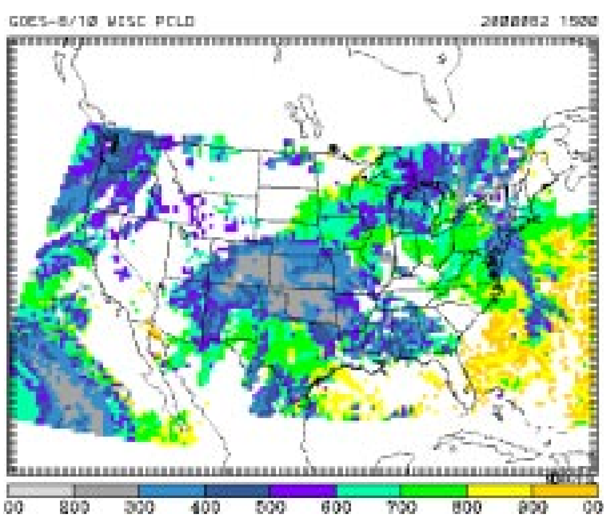

Figure 7. GOES sounder-based cloud-top pressure data used in the RUC cloud analysis. The nearest GOES cloud-top datum is assigned to each grid point.

5. SUMMARY

A cloud analysis technique for the RUC has been revised and incorporated into a parallel 1-h assimilation cycle. From 27 May to 30 June 2000, a cycle with hourly assimilation of GOES cloud-top pressure using this revised technique (along with other observations) was run in parallel with a control cycle without GOES cloud data. Verification results showed a strong positive impact from the GOES cloud assimilation on subsequent cloud-top forecasts for 1-h and 3-h forecasts, and a weaker positive impact out to 12 h. The effect of the GOES cloud assimilation on 3-h MAPS relative humidity forecasts was also found to be positive, correcting an earlier deficiency.

The GOES sounder-based cloud-top pressure data are timely and provide good coverage for the RUC domain, but this initial RUC cloud analysis still does not take complete advantage of the full-resolution satellite information. For example, the total number of cloud-top data processed for the RUC grid from both GOES platforms (8 and 10) is about 10^4, but the number of data used in either cloud building or cloud clearing is about $3*10^3$. This reduction occurs in large part because of the difficulty in assimilating fractional cloud data within a grid volume. However, this problem will be improved with the upcoming 20-km RUC (Benjamin et al. 2000) which will be able to resolve many of the cloud areas considered fractional at 40-km resolution. Methods to merge of GOES sounder and imager data for cloud analysis are under development.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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