4.3 QUANTITATIVE USE OF SATELLITE IMAGE DATA FORMATTED FOR AWIPS

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1. INTRODUCTION *

Advances in numerical weather prediction (NWP) and computer technology allow the capability for locally generated high-resolution weather analyses and forecasts. The observations that feed these state-of-the-art NWP systems will come from a variety of sources likely managed by an Advanced Weather Information Processing System (AWIPS). One important data source needed is from satellite. Currently visible and infrared (IR) satellite data are an important part of the product suite needed for operational weather prediction at the National Meteorological Center (Hoke et al., 1989). Clearly, in data-void regions satellite may offer the only quantitative source of information for NWP. And over land, where observations are separated by large distances, satellite data are critical to further define atmospheric structure. For NWP, there will always be an important need for satellite data with high-spatial resolution and numerical precision.

For most weather forecasting stations satellite data will be available only through a source that specifically formats the data for AWIPS. The AWIPS-formatted satellite data, hereafter referred to as ASD, have degraded spatial resolution and less numerical precision than the same data obtained from direct-readout ground station receiving systems. This is due to limited data transmission rates and bandwidth considerations. However, ASD will support AWIPS with satellite data for imaging purposes. With this in mind, the fundamental question arises, "Will the ASD have sufficient resolution for quantitative use in local weather analysis and forecasting?" While the answer to this question is somewhat dependent on user needs, ultimately we want to know how the degraded ASD compares with satellite data that have finer spatial resolution and numerical precision. After that, the sensitivity of the ASD on NWP can be evaluated. This paper reports on a study of the problem of degraded satellite data resolution and the impact on objective analysis that use high resolution satellite data and ASD.

2. DATA

Prior to the successful launch and subsequent transmission of data from the lastest Geostationary Orbiting Environmental Satellite (GOES-8), the Forecast Systems Laboratory (FSL) had been acquiring satellite data from GOES-7. The data were ingested both from a ground station receiver (hereafter, raw data) and also through an ASD link. Therefore, the opportunity to compare GOES-7 data at different numerical precision (bit string length) and spatial resolution has been possible. The data available for this comparison study are the 11.2μ brightness temperatures (Tb) and the visible digital count information.

The ASD IR is offered in 8-bits, while raw IR satellite data have 10-bit numerical precision. Furthermore, in the IR, ASD comes as pixel display counts whereas the direct readout data are in the form of count values representative of measured radiance. In other words, not only is there a loss of 2-bits of numerical precision, but the ASD must be rescaled to radiance count values for conversion to brightness temperature. In the case of visible data, ASD provides full 6-bit numerical resolution. Therefore, visible data differences will primarily be in registration (discussed below). The spatial resolution of northern hemisphere ASD is 9-km for both IR and visible while the raw data are nominally 8-km for IR (GOES-7) and 1-km for visible data. For GOES-7 data there may be significant information lost particularly in the visible data.

The period 12-24 July 1994 was arbitrarily selected for this study. Due to the vast amount of data, we chose 1800 UTC as the comparison time for all days except the 18th and 19th, when 1800 UTC was missing. In addition to this, we also selected the 12-h period between 1200 and 2300 UTC on July 20 to study the impact of diurnal cloud development.

The first eight days were characterized by stable and dry conditions with only weak convection developing over mountainous terrain. The clouds observed during this period were predominately middle and high level with relatively warm tops (compared to cirrus anvils resulting from deep convection). Late on 19 July however, a strong Pacific cold front passed through Colorado. On the 20th, post frontal upslope flow over eastern Colorado and increased moisture over the mountains resulted in significant cloud cover throughout most of Colorado. On the next two days, 21 and 22 July, most of Colorado was clear at 1800 UTC. Then, by the 23rd, monsoon moisture had moved into the state and widespread cloudiness was observed that day and again on the 24th.

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3. METHODOLOGY

3.1 LAPS

Since our goal is to assess the quantitative value of these data for local weather analysis and forecasting, our methodology is to use the results from the Local Analysis and Prediction System (LAPS; McGinley et al., 1991). LAPS directly analyzes Tb and visible count data on a 61 by 61 grid with 10-km spacing centered over Colorado. For this study two versions of LAPS satellite data processing are installed. One process uses the raw direct readout satellite data available from the ground station receiver (raw LAPS) while the other process uses ASD (ASD-LAPS). Because both LAPS analyses operate on the same domain it is possible to directly compare the results and evaluate the impact of the resolution differences and image to radiance conversion.

Our approach for evaluating the difference between the two LAPS results is to compute root-mean-squared and absolute differences for each analysis time. We also will present representative scatterplots for all gridpoints for two time periods for both the Td and visible counts. These diagrams reveal the amount of scatter between the two analyses.

3.2 LAPS Satellite Analysis

Prior to analyzing at 10-km, the ASD IR image counts are converted to corresponding radiance counts. The function used for this conversion is plotted in Fig. 1. It should be kept in mind that while the function that converts the raw data to Tb is similar to that in Fig. 1, the raw data function has four times the precision as that for ASD.

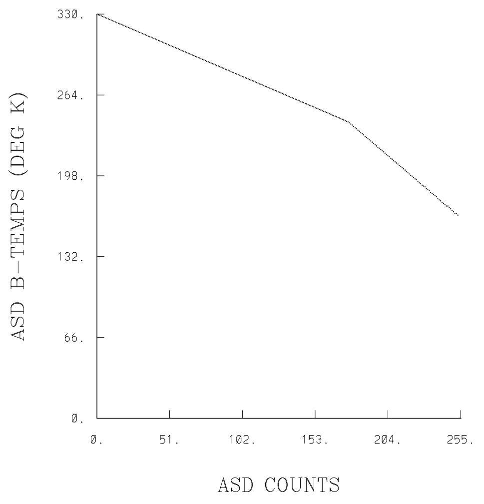

Figure 1. Functional dependence relating ASD IR counts and brightness temperatures.

The methods with which LAPS analyzes ASD and raw data follows. For both raw IR and visible data, LAPS determines the number of data pixels within a bounding grid cell centered on each gridpoint and computes the average value. In the case of 1-km visible data this is approximately 100 points. On the other hand, since the ASD have nearly the same spacing as the LAPS grid, the ASD-LAPS process uses bilinear interpolation to determine gridpoint values.

4. RESULTS

4.1 20 July 1994 - 1200 through 2300 UTC

First we will present the results for the 12-h period on 20 July. The root-mean-squared (rms) and absolute differences are presented in Table 1. As previously mentioned, post-frontal upslope clouds occupied much of eastern Colorado, while the remaining areas were clear. Upslope clouds have very uniform cloud top temperatures with very few breaks and distinct cloud edge, and cloud element detection will not degrade much as a result of satellite resolution differences. The small differences for both the IR and visible data up through 1600 UTC reveal this. Later that day, however, dissipation of the upslope cloud, and cloud development over the mountains resulted in larger differences. Overall, though, the differences are small.

Table 1: RMS and absolute differences (°K) for LAPS Tb and visible count comparison between 1200 and 2300 UTC 20 July 1994.

To further illustrate the comparison between the two LAPS satellite analyses, scatterplots are constructed for all 3721 points (61x61) for both the Tb and visible at two separate times. Figures 2 and 3 contain the IR Tb scatterplots at 1500 and 2100 UTC, respectively, while Figs. 4 and 5 show the visible count scatterplots at those times. The IR comparison at 1500 UTC indicates good agreement (Fig. 2). At 2100 UTC the Tb comparison (Fig. 3) shows two disctinct regimes: the warmer temperatures from the cloud free region existing over northern Colorado (Tb $\geq$ 290 K), and the colder cloud top temperatures (Tb $<$ 270 K) associated with the remaining upslope cloud and the deeper convection developing over south-central Colorado. Note that the scatter is much greater for the clouds. The visible comparison at 1500 UTC (Fig. 4) shows two distinct regimes: the dark cloud free areas with low albedo (low counts), and the brighter upslope cloudiness with high albedo. Note that the scatter is greater for counts between these two regimes (that is, for counts between 16 and 24) which is likely due to small cloud elements (that is, partial cloud cover within a LAPS grid cell), poor cloud edge definition, and small scale differences in albedo associated with terrain. At 2100 UTC the scatterplot of visible counts (Fig. 5) illustrates much more scatter associated with the bright cloud areas (counts $>$ 25) versus the clear areas. In the next section we will see that the visible comparison for this day when compared with other days (at least at 1800 UTC) is one of the poorest. Overall, the IR compares best, as we would expect since the raw data are more closely matched in spatial resolution with ASD than are the visible. On the other hand, GOES-8 IR data will have 4-km spatial resolution, which, if analyzed on a 10-km grid, will result in loss of information.

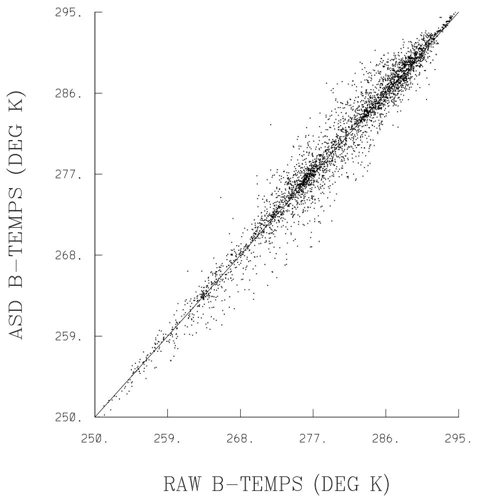

Figure 2. Scatterplot of raw LAPS versus ASD LAPS brightness temperatures (°K) for 20 July 1994 at 1500 UTC.

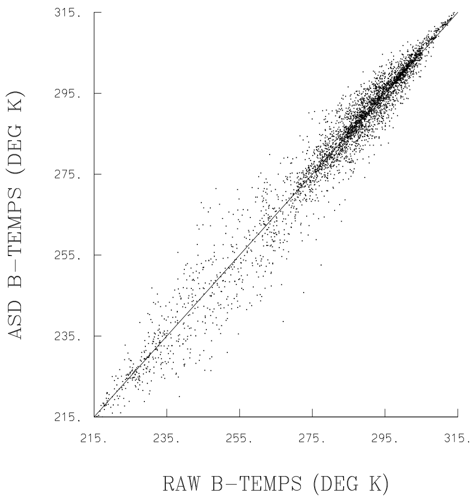

Figure 3. Same as in Fig. 2 except at 2100 UTC.

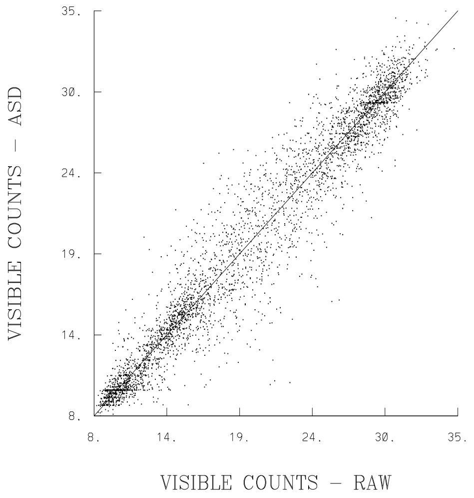

Figure 4. Scatterplot of raw LAPS versus ASD LAPS visible counts for 20 July 1994 at 1500 UTC.

4.2 12-24 July 1994 1800 UTC

To illustrate the day-to-day variation in difference magnitude that one might obtain using the ASD versus raw data, we have computed rms and absolute difference for several days at 1800 UTC. These differences, for both Tb and visible counts, are presented in Table 2. It is worth noting that the difference in Tb for 20 July is low relative to the other days. This, we believe, is due to the IR appearance of uniformity in the upslope cloud top temperatures and the absence of early mountain convection. On the other hand, this day has one of the worst com-

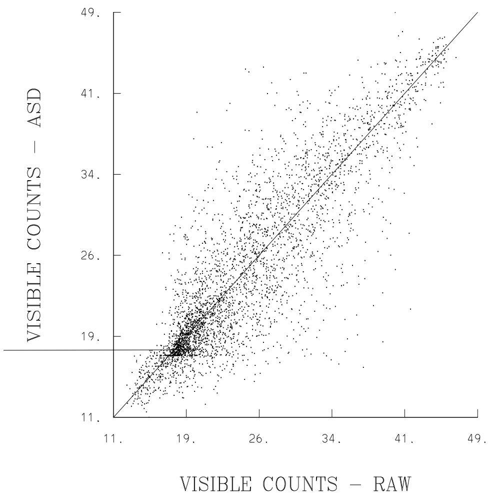

Figure 5. Same as in Fig. 4 except at 2100 UTC.

Table 2: RMS and absolute differences (°K) for LAPS Tb and visible count comparison for 10 days during July 1994 at 1800 UTC.

parisons in the visible data. Close inspection of the visible image at 1830 UTC (not shown) reveals significant small scale variation in the upslope cloud field. Since LAPS averages visible pixels while ASD is generated by a process that uses every ninth visible pixel, it is likely that a scatterplot such as the one shown in Fig. 4 would be produced. That is, there is a large amount of scatter but very little bias. Also note that on 21 July Colorado was virtually clear at 1800 UTC while on the 15^{th} and the 24^{th} convective cloud development was in progress.

5. DISCUSSION AND SUMMARY

The quantitative use of satellite image data will be required for objective analysis and prediction in local weather offices. For objective analysis purposes, it appears that the low resolution IR ASD compares favorably with higher-resolution IR satellite data from a direct readout receiver. The visible data did not compare as well due to the greater difference in spatial resolution between the two data sources. Accurate identification of clouds in objective analyses is important for the initial fields in NWP.

In this study the 11.2μ IR brightness temperatures compared very well since the nominal resolution of this data is very close to the 10-km grid spacing within LAPS. However, while the statistics show that the Tb differences over the whole domain are small, they may be greater locally in regions of large temperature constrast, such as on cloud edges or over complex terrain where temperature constrast is induced by steep terrain. We found that the Tb and visible count differences grow during the day as clouds develop. Also, from the 10 days at 1800 UTC, the IR Tb difference can range from as low as approximately 1°C to as high as nearly 9°C. This wide range in Tb difference is believed to mostly depend on the character of the clouds. Specifically, as the smaller cumulus clouds develop there will be larger errors than either before this, when sky conditions are clear, or later when convection is producing solid cold cloud top anvils.

Fortunately, future GOES-8 ASD data will provide 1-km visible data. Given the good results for the IR Tb part of this study, we believe that high-resolution visible data will become very useful for local analysis and forecasting.

Additional work in this area should include a more thorough comparison of cloudy regions with regard to cloud type. Furthermore, it is crucial to study the sensitivity of mesoscale models when using initial analyses based upon the two different satellite data resolutions.

6. ACKNOWLEDGMENT

The authors wish to thank Dr. John M Brown NOAA/FSL for his helpful technical review of this manuscript. We also appreciate the editorial review from Ms. Nita Fullerton.

7. REFERENCES

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