9.4 AN IMPROVED GOES PARALLAX CORRECTION SCHEME FOR RAINFALL ESTIMATION

J. Clay Davenport*
I.M. Systems Group, Inc, Camp Springs, MD

R. J. Kuligowski
NOAA / NESDIS Center for Satellite Applications and Research, Camp Springs, MD

1. INTRODUCTION

The current generation of geosynchronous satellites exhibits considerably improved capabilities in the areas of signal quality, gridding accuracy, and sampling frequency as compared to their predecessors. These improvements have made it possible to accurately observe the life cycle of small scale, short-lived phenomena such as rapidly developing thunderstorms at very high spatial and temporal resolutions. The ability to accurately measure the growth and dissipation of thunderstorms, in turn, allows us to make predictions of precipitation amounts and locations for mesoscale and storm scale systems. One important factor for accurately estimating precipitation from satellite imagery is the position of the cloud tops as viewed by the satellite.

Accurate location of precipitation requires knowledge of the exact location of the cloud tops with respect to the ground below. This is not a problem when the cloud is located directly below the satellite; however, as one looks away from the sub-satellite point, the cloud top appears to be farther away from the satellite than the cloud base. This effect increases as you approach the limb and as clouds get higher; the apparent coordinates for high, convective cloud tops may be displaced by as much as 40km from the sea level coordinates.

One such precipitation estimation technique, the Hydro-Estimator (HE; Scofield and Kuligowski 2003), is in operational use by the National Environment Satellite Data and Information Service (NESDIS) at the National Oceanic and Atmospheric Administration (NOAA). Since 2001 it has utilized a parallax correction technique described by Vicente et al. (2002). While it provided a reasonably good adjustment, it is limited by its use of the US Standard Atmosphere to convert the observed cloud top temperatures into cloud top heights. Furthermore, it betrayed its roots as a convective precipitation algorithm by only making adjustments to clouds that exceeded 20,000 feet (6060 m) in height.

2. UPDATED VERSION

Continued improvements in computers have led to improved atmospheric forecast models. The operational NOAA / National Centers for Environmental Prediction (NCEP) North American Mesoscale (NAM) model today is updated twice as frequently today as in 2001, with higher resolution in both the horizontal and vertical dimensions. Computer speeds have also improved for end users, giving us the ability to use the more detailed information available in the NAM to derive the cloud height within the tight time constraints of an operational product. At present, we usually have access to products that have no more than six hours of forecast motion from an objective initialization. We decided this would allow us to use reliable, short-term forecasts from the NAM to produce a map of the atmosphere's vertical structure.

Satellite IR imagery is first adjusted to remove the effects of viewing angle on cloud top temperatures, as there is an increasingly strong cold bias as we move away from the sub-satellite point (Joyce et al. 2001). The (apparent) position of each pixel is compared to the vertical temperature profile of the NAM forecast at the nearest gridpoint and time. In order to eliminate confusion from inversions (either at the surface or tropopause), we first compare the cloud top temperature to the modeled 600 mb temperature; if the observed cloud is colder than that we ascend our profile, if warmer we descend, until the first time that the observed temperature is bracketed. The heights are linearly interpolated between the bracket bounds.

Once the cloud height is known, the calculation of parallax proceeds as outlined in Vicente et al. (2002).

3. COMPARISON OF OLD AND NEW METHODS

We compared the accuracy of the old and new methods by examining a roughly 20-degree wide strip of land in the western United States and Canada, centered on 105°W longitude. The region was

---

* *Corresponding author address:* J. Clay Davenport, I. M. Systems Group, Inc., Camp Springs, MD 22201; e-mail: Clay.Davenport@noaa.gov

examined from both the eastern (GOES-12, located at 75°°W, and GOES-10, at 60°W) and western (GOES-11, at 135°W) GOES at identical times. Data was collected for 485 pairs of images between 4 September 2007 and 9 January 2008. Because we are seeing these clouds from two widely separated vantage points, their needed parallax corrections come from different directions – in portions of the image, at right angles or more. We expect to see the largest differences in the coldest tops. In the ideal case, with temperatures, heights, and locations all perfectly known, the pixels from each satellite should be adjusted to the exact same location and value. In practice, differences in calibration between the two satellites, errors in positioning, and changes introduced by re-mapping the two images into identical projections create small differences; still, we would expect the better technique to have higher correlations and lower root-mean-square errors in direct comparisons.

That is exactly what we see in Table 1, which describes the differences between the zenith-angle only adjustment (i.e., no parallax adjustment), the old method described in Vicente et al. (2002), and this method. When all pixels are considered, the differences among the three are slight. As we limit our data to progressively colder samples, the differences among three versions becomes increasingly apparent.

Table 1. Correlation and root-mean-square errors (RMSE) between simultaneous images taken from GOES-East and GOES-West, evaluated at different temperature thresholds.

a) All pixels (N=242,500,000)

	Correlation	**RMSE (K)**
No adjustment	0.867	14.25
Old method	0.882	13.18
New method	0.898	11.71

b) Pixels with initial T <= 250 K (N=53,428,600)

	Correlation	**RMSE (K)**
No adjustment	0.432	18.93
Old method	0.614	15.24
New method	0.658	13.66

c) Pixels with initial T <= 230 K (N=9,638,504)

	Correlation	**RMSE (K)**
No adjustment	0.242	13.34
Old method	0.572	8.06
New method	0.622	7.50

d) Pixels with initial T <= 210 K (N=280,613)

	Correlation	**RMSE (K)**
No adjustment	0.118	7.94
Old method	0.484	3.50
New method	0.582	3.23

The difference between the original and new parallax correction methods is also illustrated in Fig. 1 for 0100 UTC October 2007 over the northern Plains. The unshifted GOES-West and –East images are shown in panels (a) and (b), and the second set of panels show GOES-West (c) and –East (d) after applying the original parallax correction. The black pixels represent areas where pixels have been moved by the parallax correction and not replaced by other data. Normally these pixels are filled in with an average value from the surrounding pixels, but here they are left blank to highlight the direction and magnitude of the parallax correction. Note the large separation between the colder tops and lower clouds across the entire northeastern side of the main cloud body for the GOES-West image (c) and the northwestern side of the main cloud body for the GOES-East image (d). In the final two panels the new parallax correction has been applied to the GOES-West (e) and –East images (f). Note the separation shadows for lower, warmer clouds and the reduced shift of the coldest cloud tops relative to their own borders.

4. CONCLUSION

This paper provides an improvement on an existing operational product for estimating the precise location of cloud tops, by using real observed data and short-term forecasts in place of a static atmosphere. While, from a synoptic scale, the exact pixel location is of little consequence, products using this system are frequently used in flash flood events and have been used in retrospective examinations of landslides (Wieczorek et al., 2001) where the ability to precisely able to identify the regions of heaviest rain is critical. Furthermore, because the new correction is applied to all pixels, and not just to the coldest ones, it preserves the overall cloud statistics better than before – this is of particular value to the HE, which uses statistical measures around a pixel to assess its rain rate.

5. ACKNOWLEDGMENTS

This work was supported by the NOAA / NESDIS / Office of Satellite Data Processing and Distribution GOES I-M Product Assurance Plan (GIMPAP). The contents of this conference paper are solely the opinions of the authors and do not constitute a statement of policy, decision, or position on behalf of NOAA or the U.S. Government.

6. REFERENCES

Joyce, R., J. Janowiak, J., and G. Huffman, 2001: Latitudinally and seasonally dependent zenith-angle corrections for geostationary satellite IR

brightness temperatures. *J. Appl. Meteor.*, **40**, 689-703.
Scofield, R. J., and R. J. Kuligowski, 2002: Status and outlook of operational satellite precipitation algorithms for extreme-precipitation events. Wea. Forecasting, 18, 1037-1051.
Vicente, G.A., J. C. Davenport, J.C., and R. A. Scofield, 2002: The role of orographic and parallax corrections on real time high resolution satellite rainfall rate distribution. *Int. J. Remote Sens.*, **203**, 221-230.
Wieczorek, G.F., H. C. McWreath, and C. Davenport, 2001: Remote rainfall sensing for landslide hazard analysis. *U.S. Geological Survey open-file report 01-339*.

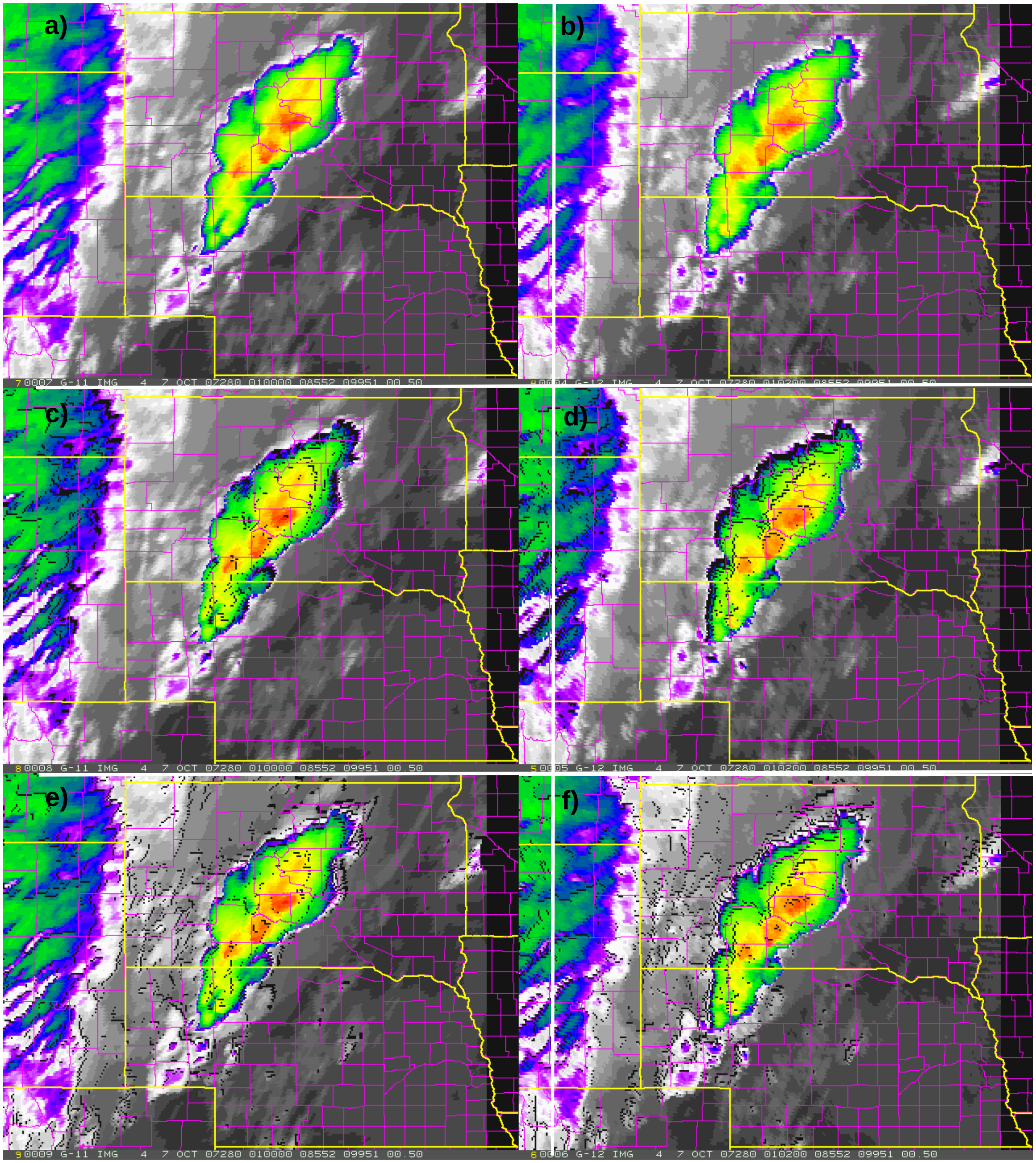

Figure 1. An example of the parallax shifts for a system over South Dakota and Nebraska at approximately 0100 UTC 7 October 2007, taken from GOES-West and GOES-East. Panel (a) is the unshifted GOES-West image, with corrections for zenith-angle only; (b) is the corresponding GOES-East image. Panels (c) and (d) are the GOES-West and –East images after parallax adjustment using the older method. Panels (e) and (f) are the GOES-West and –East images after parallax adjustment using the new method described here.