

a result of the instability, produces the severe surface wind by bringing down high-speed air from middle levels. Severe storm warnings should be issued if small convective echoes form on radar when there is strong wind aloft.

ACKNOWLEDGEMENTS

I would like to thank John Curran and Lawrence Hughes for their highly constructive comments during the development of this paper. I also would like to express large thanks to Sid Cornell, Computer Supervisor, NSSFC, Kansas City, who provided the data and had patience to rerun the data when I made a large mistake.

REFERENCES

Galway, J. G., 1956: The Lifted Index as a Predictor of Latent Instability. *Bulletin American Meteorological Society*, 37, pp. 528-529.

McCann, D. W., 1975: *A Kinematic Severe Thunderstorm Model Based on Tornado Proximity Soundings*. M.S. Thesis, University of Missouri, Columbia, MO, 102 pp. (Unpublished).

Miller, R. C., 1972: Notes on Analysis and Severe Storm Forecasting Procedures of the Air Force Global Weather Central. *Technical Report 200 (Rev.)*, 190 pp.

Showalter, A. K., 1953: Stability Index for Forecasting Thunderstorms. *Bulletin American Meteorological Society*, 34, pp. 250-252.



VERIFICATION OF SATELLITE DERIVED CLOUD TOPS

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ABSTRACT

This study was done to get a sample verification of the cloud tops which are operationally derived from GOES satellite data by the Synoptic Analysis Branch of the NESS. Satellite tops were compared with the routinely available radiosonde data and pilot reports where available. The satellite tops in this sample deviated from actual tops by an average of only 2000 feet. A large majority were off by 3000 feet or less and close to 50% deviated from actual tops by 1000 feet or less. The results show the credibility of satellite-derived cloud tops.

1. INTRODUCTION

Since 1975, satellite cloud tops have been derived operationally by the Synoptic Analysis Branch (SAB) of the National Environmental Satellite Service (NESS). The Man Machine Interactive Processing System (MMIPS) is used to obtain the cloud-top temperatures from GOES Infrared (IR) satellite imagery, and the heights are based on the NMC Global Model Analysis and/or forecast.

After a manual edit, the satellite-derived tops are plotted on the Experimental Satellite Cloud Analysis which is prepared by the Synoptic Analysis Branch (SAB) and transmitted on NAFAX at 1240 GMT. Four times per day SAB personnel prepare cloud heights for the NMC Aviation forecaster and they are also transmitted by the Washington Satellite Field Services Station (SFSS) on the national teletype circuit under the TBXX10 KWBC heading for 09Z, 15Z, 21Z and 03Z.

Verification of these satellite-derived cloud tops is difficult to obtain. In this study attempts to verify against radiosonde data, the most regularly

available source of data, and pilot reports, when available, were used. It should also be noted that the cloud tops used in this study were generated independently from the normal SAB operation, although the methods used were the same.

2. METHOD

Satellite images were examined for clouds that appeared to have uniform tops over a large area, especially those near radiosonde stations. Since dew point appears on soundings only when temperatures are $\leq -40^{\circ}\text{C}$ (about 30,000 feet), no attempt was made to verify cirrus tops above this level or convective (thunderstorm) tops. Because the resolution of data used on the MMIPS is 4 km, tops were considered to be uniform over an area at least 4 x 4 km.

Next, the MMIPS (Bradford, 1975) was used to obtain cloud-top temperatures. The 0900 GMT operational data was used on five days and the 1100 GMT data used on the other day of this study. A fine frequency distribution of the cloud temperatures in the area of interest was displayed

on the MMIPS CRT. In an attempt to get average tops, the temperatures chosen for the cloud tops were the peak-count values from the frequency distribution. If several peaks were seen, the one which seemed best to represent the cloud top, usually the coldest peak, was chosen subjectively.

Data cards for each location were prepared and a computer program was used to obtain cloud top heights from the temperatures using the NMC Global Model (Cooley, 1974). The cloud top obtained is the height at which that temperature occurs at that location in the model. The 24-hour forecast model was used for points north of 40°N and the 0000 GMT analysis was used for points south of 40°N because experience has shown that, at this time of day, this combination of forecast and analysis gives the best results.

The 1200 GMT pilot reports and 1200 GMT soundings were then obtained and compared with the satellite tops. When the moist layer on the sounding or the cloud top from a pilot report seemed to be the same cloud seen and measured on the satellite, a verification was made. The criteria for cloud/no cloud on the sounding was a temperature/dew-point depression of 5°C or less which usually shows as a sudden vertical change in the dew point (See sounding examples in Figures 2, 4, 6, and 8). All values were rounded off to the nearest thousand feet.

This was done for six days which resulted in a total verification of 105 cases.

3. PROBLEMS

There was a three-hour difference between the satellite measurement and the soundings and pilot reports. Clouds can move, develop, and dissipate significantly in three hours. When verifying tops, consideration was given to this time difference.

The biggest problem with soundings is that often the vertical moisture change is so gradual that it is difficult to estimate where clouds begin and end. In these cases, the arbitrary criteria mentioned earlier was used. Sometimes soundings meet the moisture criteria and no clouds are observed. Also, cloud tops from soundings, as well as pilot reports, are sometimes questionable because radiosonde values are obtained for instantaneous points while satellite images better reflect the areal cloud distribution.

Obtaining tops from pilot reports also presents problems. Pilot reports are often incomplete and show a large variety of tops reported in the same area at the same time.

Thin layers of clouds (other than black-body radiators) were a real problem and may account for some of the results where satellite tops were lower than actual tops. Only clouds which

appeared to be good black-body radiators were used. There is an emissivity algorithm (Young, 1975) available on the MMIPS which is occasionally used for calculating the temperature of thin clouds, but it is not often used to derive cloud-top temperatures and was not used in this study. Another possible source of cloud-top height error is the NMC analysis and forecast fields (Cooley, 1974). Comparison with actual observations and analyses often shows errors, although often small, which can have a large effect on cloud tops. This is most noticeable in the forecast models.

4. EXAMPLES

A. The first example considers a large area of stratus that developed from Georgia northward to Pennsylvania when a back-door cold front dropped southward to the Carolinas and became stationary. The table shows the satellite tops compared with the soundings and pilot reports. The satellite tops compared with the Dulles Airport, VA (IAD) sounding may be too far from IAD for valid comparison, but were used in the statistics. Notice that for low clouds such as in this example, the difference between satellite tops and actual tops is more significant than it would be for middle- or high-level clouds. See Figures 1 and 2 for the satellite picture used for this case and the sounding for Athens, GA (AHN). In Figure 1, sounding tops are plotted next to station identifiers and satellite tops are plotted

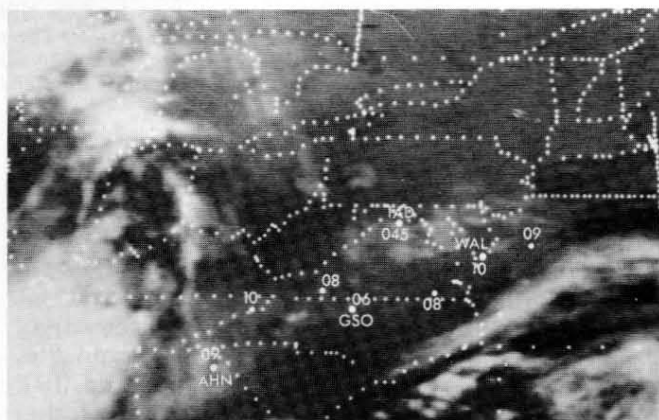


Figure 1. GOES-I Infrared Picture, 0900 GMT, 31 May 1977.

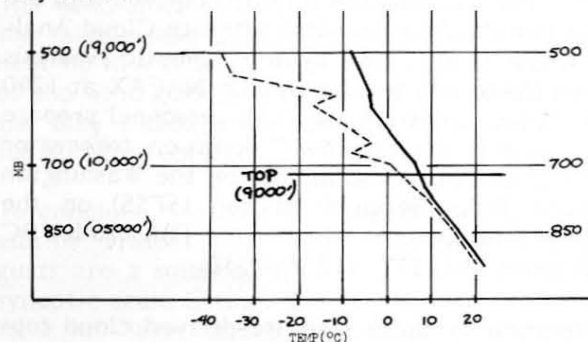


Figure 2. Athens, GA (AHN) Sounding, 1200 GMT, 31 May 1977.

where the cloud-top temperatures were measured. Notice in Figure 2 how the top could extend up to 10,000 feet where moisture suddenly decreases, but was chosen at 9000 feet using the 5°C temperature/dew-point criteria.

B. The second example, Figure 3, shows cirrus topping multiple-layered cloudiness along a cold front from northern Georgia northward to West Virginia and eastward to the Del Marva Peninsula. The satellite-derived cloud top near the Virginia-North Carolina border was assumed to move over WAL by 1200 GMT. Notice in the Table that in this case all satellite tops were higher than the sounding tops. Figure 4 shows the clearly defined sounding top at Greensboro, NC (GSO).

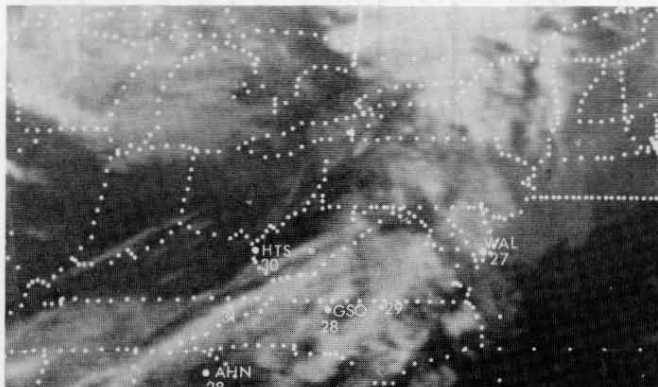


Figure 3. GOES I Infrared Picture, 0900 GMT, 1 June 1977.

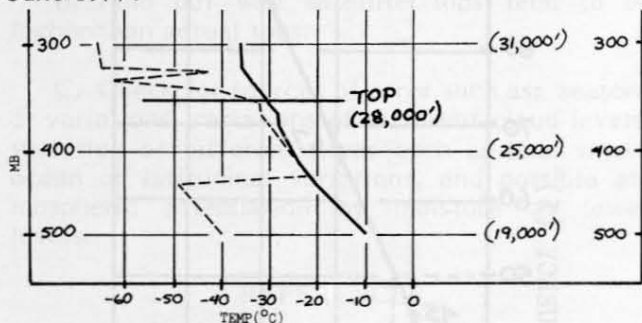


Figure 4. Greensboro, NC (GSO) Sounding, 1200 GMT, 1 June 1977.

C. The third example is for middle-level clouds over the Southwest and Rockies. There is a weak surface high over the "four corners" area and weak lows over northern Utah and eastern Colorado. Here, the inflow of moisture is mostly at 500 mb from the southwest. Tops appear to be fairly uniform over a large area (see Figure 5 and Table 1). The sounding cloud top is clearly seen on Figure 6. Also notice that moisture increases again above the estimated top showing the presence of higher layers which also showed up on other station soundings. These higher clouds appear as brighter areas on the picture in Figure 5.

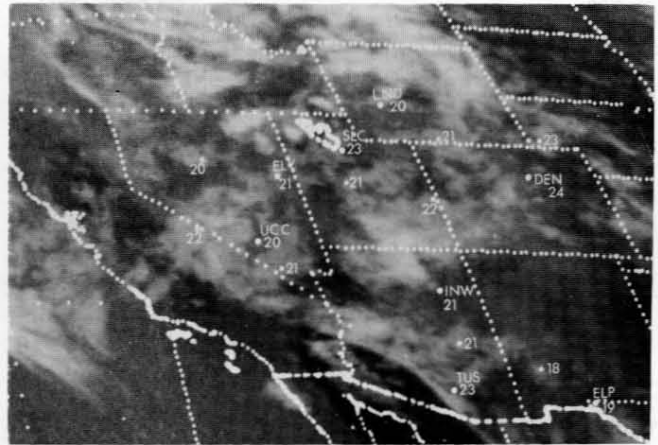


Figure 5. SMS 2 Infrared Picture, 0945 GMT, 8 June 1977.

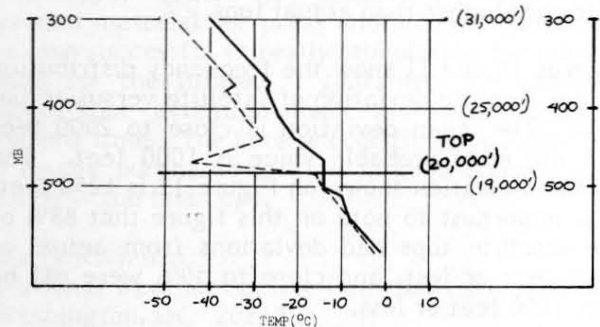


Figure 6. Yucca Flat, NV (UCC) Sounding, 1200 GMT, 8 June 1977.

D. This is a good example of mid-level cloud verification. The clouds in Illinois and Indiana are located on the cold side of a warm front. This cloud layer shows up distinctly (see Figure 7). The cloud top can be clearly seen in Figure 8.

5. RESULTS

The histogram in Figure 9 shows the frequency distribution of the deviation of satellite tops from actual (sounding and pilot report) tops. This figure shows that the mode (the most probable deviation) is 1000 feet higher than the actual tops

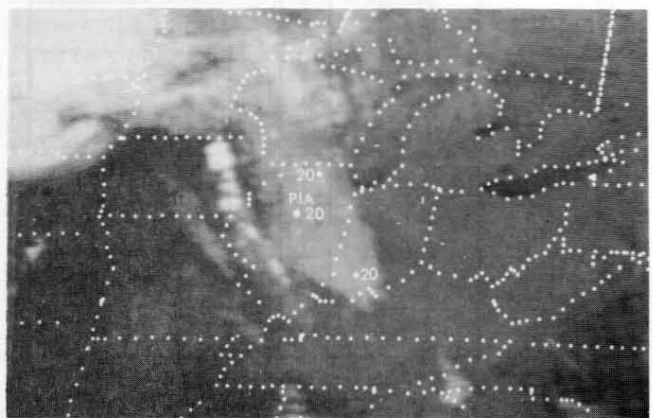


Figure 7. GOES-I Infrared Picture, 0900 GMT, 10 June 1977.

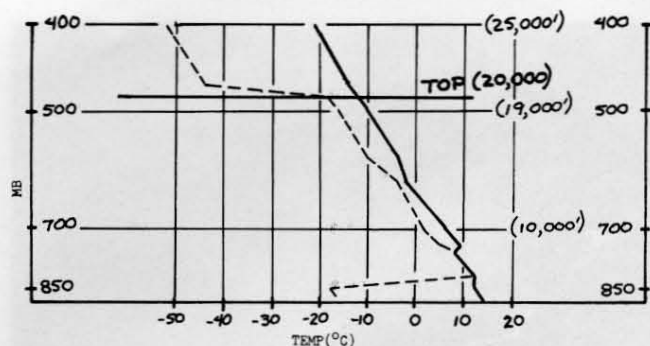


Figure 8. Peoria, IL (PIA) Sounding, 1200 GMT, 10 June 1977.

which is also close to the mean value (+712 feet). A secondary mode is apparent at 3000 feet above actual. This figure shows that the deviation of satellite tops from actual tops is definitely skewed toward higher than actual tops.

Figures 10 and 11 show the frequency distribution of the absolute deviation of satellite versus actual tops. The mean deviation is close to 2000 feet and the most probable value is 1000 feet. The median deviation shown on Figure 11 is 1250 feet. It is important to note on this figure that 88% of the satellite tops had deviations from actual of 3000 feet or less, and close to 50% were off by only 1000 feet or less.

6. CONCLUSION

This study shows that the cloud tops obtained by using this blend of satellite-derived temperatures and NMC height fields produced reasonable results. This is especially true when you consider all the possible sources of error involved in obtaining

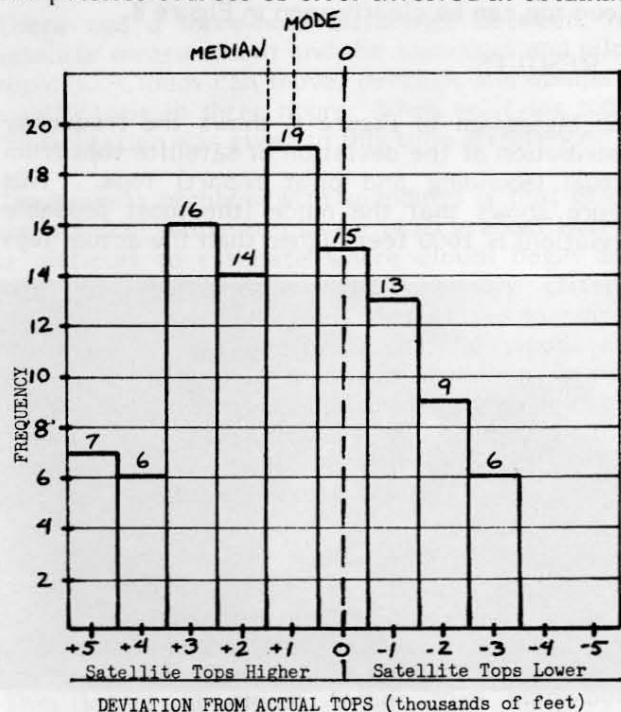


Figure 9. Histogram of Frequency Distribution of Deviation of Satellite Tops from Actual Tops.

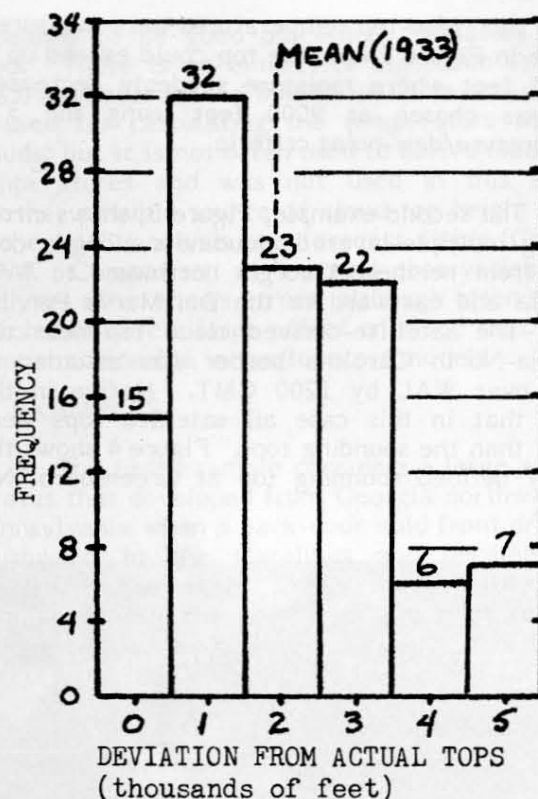


Figure 10. Histogram of Frequency Distribution of Absolute Deviation of Satellite Tops from Actual Tops.

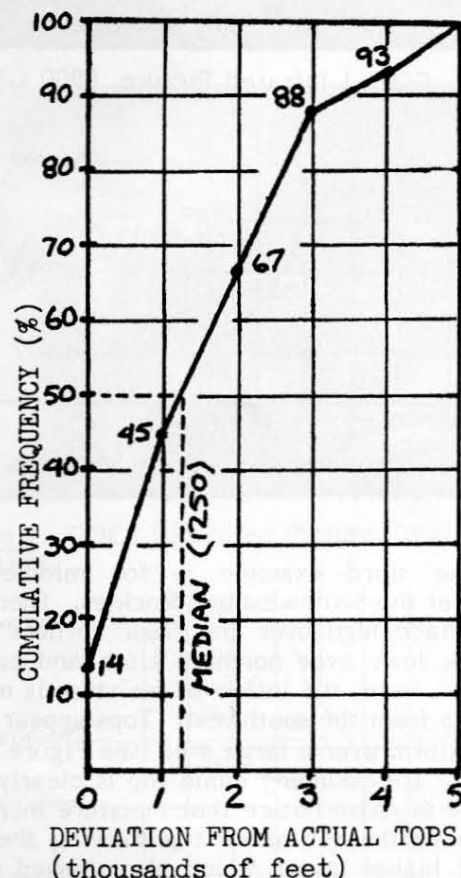


Figure 11. Graph of Cumulative Frequency Distribution of Absolute Deviation of Satellite Tops from Actual Tops.

Table 1. Satellite Tops Compared to Sounding Tops and Pilot Reports.

DATE	SATELLITE TOPS	LOCATION	SOUNDING TOPS	PIREPS
5/31/77	100	ABN	090	060
	090	WAL	100	
	080	GSO	060	
	080	near RDA		
6/1/77	080	LAD	045	
	310	ABN	280	
	290	WAL	270	
	310	GSO	280	
6/8/77	310	HTS	300	
	210 & 240	DEN	240	
	210	LND	200	
	210	SLC	230	
	210	ELY	210	
	210	UCC	200	
	210	INW	210	
	210	TUS	190 or 230	
6/10/77	180	ELP	190	
	200	FLA	200	

the satellite tops and also in considering the method of verification. The most important thing to notice is that satellite tops are in error by only 2000 feet, on the average. This makes them especially good "observations" at the middle- and high-levels of the atmosphere. It is also important to note that 88% of the cases in this study were only in error by 3000 feet or less, and close to 50% were off by only 1000 feet or less.

The results of the study also show that there is a definite tendency for satellite tops to come out higher than actual tops.

7. IDEAS FOR FUTURE STUDY AND DEVELOPMENT

A. Develop an automated system for verifying operational satellite tops.

B. Find out why satellite tops tend to be higher than actual tops.

C. Check for sources of error such as: seasonal variations, variations of different cloud levels, variation of different areas such as land versus ocean or latitudinal variations, and possible atmospheric attenuation by moisture at lower levels.

REFERENCES

Bradford, R. E., W. B. Walthan, and M. M. Kazmerczak, 1975: The Man-Machine Interactive Processing System. *NOAA Technical Memorandum NESS 64*, March, pp. 83-93.

Cooley, D. S., 1974: A Description of the Flattery Global Analysis Method -- No. 1. *Technical Procedures Bulletin No. 105*, January.

Young, M. T., 1975: The GOES Wind Operation. *NOAA Technical Memorandum NESS 64*, March, pp. 112-115.

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tion (available from routine sources) is carefully figured into the flight planning the booms can be avoided.

During the tests, sonic boom monitoring and recording equipment was positioned on Coast Guard cutters off the coast of Maryland, Virginia, and Delaware while aircraft passed over at 36,000 feet traveling at speeds between Mach 1.05 and Mach 1.2 -- as fast as 765 miles per hour. All eight test flights were boomless.

BOOK CORNER from page 34

In closing, I would strongly recommend *The Genesis Strategy* to each and every operational weather type. It not only contains excellent background material for press and public inquiries but is also successful in really stimulating the mind to plan for the future. I guarantee the book will keep your attention even while reading it in leisure time. The book was difficult to obtain and I finally purchased it at a large university book store -- the last copy.

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LETTERS TO THE EDITOR

To the Editor:

Alas, life is truly cruel! A chance to fame as critic and book reviewer has not only been utterly devastated but vaporized into obscurity. A scoundrel, nay, a cad by the name of Galloway has done this to me. The brazen bounder is a plagiarist. And not a very clever one at that. Word for word he has purloined what once was mine. Oh, how the blow of the hammer would have been softened, the blade of the guillotine dulled, had there appeared at the end of the book review the caption, "Reviewer's Name Unavailable Due to Computer Failure."

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