

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.

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### 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

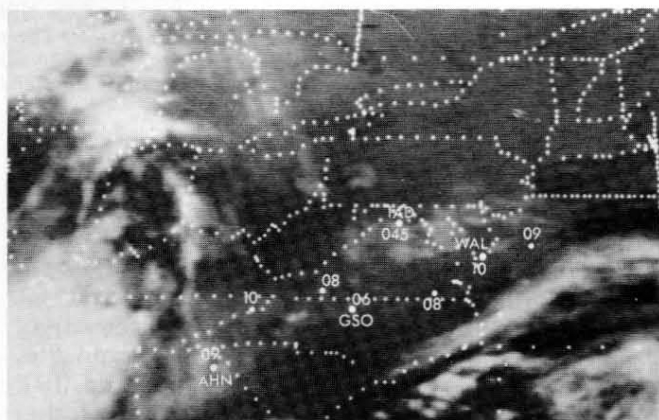


Figure 1. GOES-I Infrared Picture, 0900 GMT, 31 May 1977.

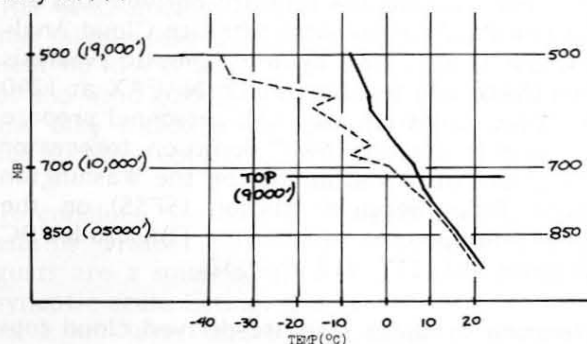


Figure 2. Athens, GA (AHN) Sounding, 1200 GMT, 31 May 1977.





