National Weather Service
Office of Meteorology

Technical Procedures Bulletin

Series No. 410

Subject:

The Satellite-Derived Cloud Cover Product (Sounder)

Program Requirements and Development Division, Silver Spring, MD 20910

FIRST BULLETIN ON THIS SUBJECT

November 28, 1994
W/OM21:CKK

This Technical Procedures Bulletin (TPB), written by Charles K. Kluepfel (NWS, Office of Meteorology), Anthony J. Schreiner (University of Wisconsin), and David A. Unger (NWS/Techniques Development Laboratory [at the time this bulletin was written]), provides the background about the development, use, and performance of the Satellite-derived Cloud Cover Product (SCP), which complements Automated Surface Observing System (ASOS) observations. This product was developed by the National Environmental Satellite, Data, and Information Service (NESDIS) Systems Design and Applications Branch and the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin-Madison, to provide cloud cover data (cloud amount and height) above 12,000 feet Mean Sea Level (MSL), and are derived from the **G**eostationary **O**perational **E**nvironmental **S**atellite/**V**isible Infrared Spin-Scan Radiometer **A**tmospheric **S**ounder (GOES/VAS).

This TPB provides an example of the SCP, explains how to read it, and addresses data availability. Sections 3 and 4 give a brief description of the theory and development of the product, while Section 5 summarizes the results of some verification studies.

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THE SATELLITE-DERIVED CLOUD COVER PRODUCT (SOUNDER)

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1. INTRODUCTION

The Automated Surface Observing System (ASOS) was developed to take advantage of advances in sensor and microprocessor technology, which make it possible to automate certain observing functions. ASOS supports the National Weather Service (NWS) modernization plans through expanded spatial and temporal coverage, objective observations, and continuous weather watch. Along with advances in remote sensing and weather information processing systems, ASOS will contribute to improved warning and forecast services by performing basic observing functions necessary to generate a Surface Aviation Observation (SAO).

One characteristic of ASOS is that its ground-based laser ceilometer is only designed to report cloud bases to 12,000 feet Above Ground Level (AGL) (Figure 1). To overcome this limitation, the National Environmental Satellite, Data, and Information Service (NESDIS) Systems Design and Applications Branch and the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin-Madison have developed a satellite technique to provide cloud cover data (cloud amount and height) above 12,000 feet Mean Sea Level (MSL).

This bulletin gives background about the development, use, and performance of the **S**atellite-derived **C**loud Cover **P**roduct (SCP) to complement ASOS. It draws upon previously published works to enable the user to better understand the capabilities, benefits, and limitations of this resource. These observations enhance a number of National Oceanic and Atmospheric Administration (NOAA) products, including hourly State Weather Roundups, and the Local Climatological Data (LCD) publication produced by the National Climatic Data Center (NCDC). Because cloud data are required around the clock, the SCP data are derived from the **G**eostationary **O**perational **E**nvironmental **S**atellite/**V**isible Infrared Spin-Scan Radiometer **A**tmospheric **S**ounder (GOES/VAS).

Section 2 gives an example of the SCP, explains how to read it, and addresses data availability. Sections 3 and 4 give a brief description of the theory and development of the product, while Section 5 summarizes the results of some verification studies.

2. THE SATELLITE-DERIVED CLOUD COVER PRODUCT

2a. SCP message

Currently, there are four regional SCP collectives available on all four regional distribution circuits of the AFOS network, the Domestic Data Service of the Family of Services, and the Information Stream Project for AWIPS/NOAAPORT (ISPAN). The AFOS and World Meteorological Organization (WMO) headers are:

Regional Collective	AFOS Header	WMO Header
Eastern Reg.	SCPER1	TBUS20 KWBC
Central Reg.	SCPCR1	TBUS21 KWBC
Southern Reg.	SCPSR1	TBUS22 KWBC
Western Reg.	SCPWR1	TBUS23 KWBC

An example of a portion of the Eastern Region SCP collective, with decoding details, is shown in Figure 2.

1 Now working at the Climate Analysis Center of the National Meteorological Center (soon to be named the Climate Prediction Center of the National Centers for Environmental Prediction)

The data included for each station in the satellite-derived cloud cover product are:

- ASOS surface observing station for which the data are calculated (usually a three letter identifier, but may be up to five characters).

- Date and time of the observation (UTC).

- Cloud coverage at the MID levels (defined as cloud tops above 631 mb, but no higher than 400 mb). In a standard atmosphere these heights are approximately equivalent to 12,000 and 23,600 feet MSL, respectively. The standard categorical breakdowns are used (Office of the Federal Coordinator for Meteorological Services and Supporting Research [OFCM] 1994): clear (CLR), scattered (SCT), broken (BKN), overcast (OVC). Mostly clear (MCLR) is used when very thin, transparent clouds may be present above 631 mb, but there are insufficient data to accurately resolve total cloud coverage and cloud top heights. See Section 4 for more details about MCLR.

- Cloud coverage at the HIGH levels (defined as cloud tops above 400 mb) using SCT, BKN or OVC.

  Note: A cloud coverage of BKN or OVC will be given for either the MID or HIGH levels. SCT layers may be reported at both MID and HIGH levels. A CLR (MCLR) report indicates clear (mostly clear) skies above 631 mb and **implies nothing about cloud coverage at or below 631 mb.**

- Range of cloud top heights (hundreds of feet MSL) from all 25 fields-of-view (FOVs) around the station (encompassing a 50 x 50 km box centered on the station). See Section 4 for more details. The lower limit is 631 mb, and the upper limit is set to the first guess of the tropopause height from the Nested Grid Model (NGM) (Phillips 1979; Tuccillo and Phillips 1986; Hoke et al. 1989). Cloud top height estimates should be used judiciously whenever thin clouds are present, especially during MCLR conditions.

- Average **E**ffective **C**loud **A**mount (ECA), given in percent. Average ECA is a measure of total cloud cover and cloud opacity and may be helpful in determining whether a cloud layer is thin. The average ECA for clear skies is zero, while the average ECA for an opaque overcast is 100. An average ECA of less than 33 (66) in the case of broken (overcast) cloud conditions indicates the likelihood of thin clouds. ECA and average ECA are explained in more detail in Sections 3 through 5.

2b. Data availability

Areal coverage of this product is currently limited to the contiguous United States[2]. One observation per hour is issued for each commissioned NWS ASOS station designated to appear in the SCP; however, due to sounder schedule variations, there are several exceptions which are explained in subsequent paragraphs. Additional reports for research sites and soon-to-be commissioned ASOS sites are also included. As the number of commissioned ASOS stations increases, so will the number of designated stations in each regional collective. If the regional collectives become too large, it may be necessary to subdivide them further.

The GOES-7 sounder (VAS) begins measuring radiances from the northern-most portions of the scan area at about 20 minutes past each hour. The scan continues southward, completing the southern-most latitude by about 30 minutes past the hour. Data processing and

2 Satellite-derived cloud products may become available for Alaska, Hawaii, and Puerto Rico in the future. The availability for Alaska will depend upon the feasibility of using Polar-orbiting Operational Environmental Satellite (POES) data, while the availability for Hawaii and Puerto Rico will depend upon future GOES positioning and the feasibility of using data from the GOES imager in cloud estimations. For GOES-8 and subsequent geostationary satellites, the use of the imager would require a change from the CO_2 technique described in this paper to an H_2O (6.7 μm) technique (Nieman et al. 1993), which is currently under development.

distribution take an additional 20 to 25 minutes, making the final product available to users by approximately 55 minutes past the hour. Due to VAS scheduling conflicts, there are times each day when satellite sounding data over certain regions of the country are delayed 25 to 35 minutes. Therefore, cloud estimates based upon these data are unavailable for the scheduled transmission and are transmitted separately. These delays affect all stations during the 1200 UTC cycle, while during the 0500, 1100, 1700, and 2300 UTC cycles, only stations south of 35°N are affected. A few soundings in southern Florida and extreme southern Texas are available from the 0500, 1100, 1700, and 2300 UTC cycles that are otherwise not available. At the time this bulletin was published (November 1994), the GOES-8 sounder schedule was not yet available; however, it is known to have a slower scan rate (52 minutes to scan the United States from north to south versus 10 minutes for the GOES-7 VAS) with improved accuracy due to better signal-to-noise definition (Menzel and Purdom 1984).

At press time, satellite cloud data were not calculated for the northeast United States due to the high viewing angle from the GOES-7 subpoint (0°N 112°W). Whenever this Local Zenith Angle (LZA) exceeds 60° (refer to Figure 3), the satellite sounding data are considered unreliable for SCP calculations. This situation is expected to change in early 1995 when GOES-8 becomes the operational geostationary satellite for the eastern United States (subpoint at 75°W) and GOES-7 is moved to 135°W for the remainder of its life. This will result in SCP data becoming available over the northeast United States; however, SCP data will become unavailable over portions of North Dakota and Montana due to the LZA limitation. GOES-J is scheduled for a mid-year 1995 launch and should become the operational geostationary satellite for the western United States about six months after launch.

Around the time of the vernal/autumnal equinox (plus or minus three weeks), the satellite operates in eclipse mode (total darkness) between 0600 and 0900 UTC. To preserve the batteries during these times, a minimum of instruments are used, making imager and sounder data unavailable.

During times of threatening severe weather over any of the contiguous 48 states, SCP data availability may decrease due to sounder schedule changes which accommodate rapid scan operations over the threatened area.

3. THE CO_2 ABSORPTION TECHNIQUE

Satellite methods of estimating cloud cover can completely miss cirrus clouds or mistake them for lower clouds. This is because the infrared brightness temperatures of cirrus are often warmer than the temperatures associated with the true altitudes of the clouds. The CO_2 absorption technique (Chahine 1974; Smith et al. 1974; Smith and Platt 1978; Menzel et al. 1983) uses data from the GOES/VAS (Wylie and Menzel 1989; Menzel and Strabala 1989; Schreiner et al. 1993) to provide a partial solution to this problem.

Radiation is measured from three infrared (IR) spectral channels (13.3, 14.0, and 14.2 μm), each of which is sensitive to CO_2 absorption at various atmospheric levels. Radiative transfer principles are then used to determine the cloud top height:

$$R_c^i - R_a^i = [ECA]^i \, [R_b^i(p) - R_a^i] \quad (1)$$

where R_c is the radiance for an FOV obscured by a cloud, R_a is the radiance for a clear column of atmosphere, $R_b(p)$ is the black body radiance at the pressure level (p) of the cloud top, and $[ECA]^i$ is the effective cloud amount at spectral band i[3]. The clear and cloudy radiances on the left hand side of equation (1) are measured by

3 $[ECA]^i$ for a given FOV at spectral band i is defined as the fractional cloud cover times the emissivity at spectral band i. Emissivity is the ratio of the emitted radiance of an object (i.e., cloud top) to the emitted radiance of a black body (perfect emitter). It measures the transparency of an object to thermal energy. A thick cloud layer would have an emissivity close to 1.0; whereas a very thin cloud would have an emissivity near zero.

the remote sounder; the data on the right hand side are estimated from operational numerical model forecasts of temperature and moisture profiles. Thus, at a given spectral band i, equation (1) is left with two unknowns (p and ECA).

A ratio of equation (1) is then established by using two spectral bands (i and j) close enough together so that the respective ECAs may be assumed to be equal:

$$\frac{R_c^i - R_a^i}{R_c^j - R_a^j} = \frac{R_b^i(p) - R_a^i}{R_b^j(p) - R_a^j} \qquad (2)$$

Then, equation (2) may be solved for cloud top pressure (p). The above calculation is done for each CO_2 spectral band, and the highest cloud top is selected. Radiances from the 11.2 μm IR window channel are then plugged into Equation (1) to calculate the ECA.

The CO_2 technique experiences difficulties when the difference between clear and cloudy radiances falls within the instrument noise level. This occurs about 20% of the time, primarily for low (warm) cloud tops, but also for very thin cirrus. Because the surface-based observation (provided by ASOS) more accurately detects low clouds, the SCP is restricted to reporting middle and high clouds. Middle clouds are defined as clouds with tops above the 631 mb pressure level, but no higher than 400 mb. Clouds with tops above the 400 mb pressure level are defined as high clouds.

The technique is generally capable of detecting only the highest cloud top within a given FOV; therefore, individual tops of multi-layered clouds within that FOV cannot be resolved. If a particular FOV has a thin cloud layer overlaying another cloud layer, this technique will likely estimate a cloud top that is between the two layers. This is because the radiance measured by the satellite will be representative of both the radiation from the top thin layer and the radiation that passes through the top layer from below. If one thin layer is present, the radiance measurement will likely reflect a level between the top of the cloud layer and the surface of the earth. This is why thin cirrus may be misidentified as low-level clouds; during these situations, the cloud top heights may be suspect.

At times a very strong surface-based temperature inversion (i.e., within Arctic air masses) may cause the radiance from the ground to be roughly equivalent to the radiance that would be expected from a mid-level cloud (due to the temperatures being similar). In such instances, the satellite may erroneously report a mid-level cloud, when it is actually responding to a very cold surface temperature.

Horizontal resolution for a single FOV ranges from 7 km (at Nadir or 0°N) to 13 km (at 60°N latitude), with a nominal value of 10 km for mid-latitudes. Therefore, small cloud elements or small cloud breaks are not easily resolved. Nonetheless, independent studies (Menzel and Strabala 1989; Evans and Snodgrass 1993) have demonstrated that when properly applied, this technique provides reliable cloud data.

4. THE SATELLITE-DERIVED COMPOSITE CLOUD OBSERVATION

For each ground observation site listed in the SCP, radiances are received for up to 25 FOVs (5 x 5 grid) centered over the site. In the mid-latitudes each FOV has a horizontal resolution of approximately 10 km. A three-step process is

Cloud Top Pressure (CTP) (mb)	Effective Cloud Amount (ECA) $\leq$ 0.33	.34-.65	.66-.95	.96-1.00
CTP < 400	b1	c1	d1	e1
400 ≤ CTP < 631	b2	c2	d2	e2
631 ≤ CTP ≤ 950	f	f	f	f
CTP > 950	a	a	a	a

NOTE: All entries in the table add up to 100%

DEFINITIONS:

a = percentage if fields-of-view (FOVs) with CLEAR sky observations

b1, c1, d1, e1 = high cloud tops

b2, c2, d2, e2 = middle cloud tops

f = percentage of FOVs with low cloud tops

s1 = b1 + c1 + d1 + e1 (sum of elements in the first row)

s2 = b2 + c2 + d2 + e2 (sum of elements in the second row)

Table 1. Template for the histogram of VAS determinations of cloud height and amount over a given ground observation site.

then used to estimate the composite cloud cover for each site (Schreiner et al. 1993).

First, an ECA and cloud top pressure (CTP) for each FOV surrounding the observation site are estimated from equations (1) and (2). A histogram is then created by stratifying the data by ECA and CTP, as shown in Table 1. The percentage of FOVs with clear sky observations is denoted by "a." High cloud tops are denoted in the table by [b1, ..., e1] and middle cloud tops by [b2, ..., e2]. Category "f" identifies the percentage of FOVs with low cloud tops. The sum of terms in the first row is represented by "s1," while "s2" represents the sum of terms of the second row. All terms in the table should add up to 100%.

Second, the decision tree in Table 2 is used to estimate the composite cloud coverage for each station. Only clouds with tops above 631 mb (MID and HIGH levels) are given in the SCP. A range of cloud top heights (hundreds of feet MSL) is given for the FOVs around each station whenever the CTPs indicate the presence of middle or high clouds. In reporting composite cloud cover, the SCP may list both MID **and** HIGH layers of scattered clouds simultaneously, while broken or overcast conditions are reported as either MID **or** HIGH. A CLR report is used for clear conditions above 631 mb and **implies nothing about cloud cover at or below that level**. The "mostly clear" (MCLR) category indicates the possible presence of very thin, transparent clouds above 631 mb. In these situations, clear radiances are reported

- If $(a + f) = 100\%$ then **CLR** (SKIP OUT)
- If $(a \geq 30\%)$
  - If $(s1 > 0\%)$ then **HIGH SCT**
  - If $(s2 > 0\%)$ then **MID SCT** (SKIP OUT)
- If $(7\% < a < 30\%)$
  - If $(f > 40\%)$
    - If $[(b1 + b2) \leq 10\%$ and $(c1 + c2) \leq 10\%$ and $(d1 + d2) \leq 10\%]$ then **MCLR** (SKIP OUT)
    - Else
      - If $(s2 < 10\%)$ then **HIGH BKN** (SKIP OUT)
      - If $(s2 \geq 10\%)$ then **MID BKN** (SKIP OUT)
  - Else
    - If $(s2 > s1)$ then **MID BKN** (SKIP OUT)
    - If $(s1 \geq s2)$ then **HIGH BKN** (SKIP OUT)
- If $(a \leq 7\%)$
  - If $(f > 70\%)$ then **MCLR** (SKIP OUT)
  - Else
    - If $(s2 > s1)$ then **MID OVC** (SKIP OUT)
    - If $(s2 \leq s1)$ then **HIGH OVC** (SKIP OUT)

NOTE: Satellite may report both MID and HIGH level scattered clouds simultaneously. BKN or OVC conditions are reported as either MID or HIGH clouds.

DEFINITIONS:
a = percentage of fields-of-view (FOVs) with CLEAR sky observations
b1, c1, d1, e1 = high cloud tops
b2, c2, d2, e2 = middle cloud tops
f = percentage of FOVs with low cloud tops
$s1 = b1 + c1 + d1 + e1$ (sum of elements in the first row)
$s2 = b2 + c2 + d2 + e2$ (sum of elements in the second row)

Table 2. Decision tree for refining the composite satellite cloud report (notation refers back to Table 1 and Section 4). Results are indicated in **bold**.

by less than 30% of the FOVs around the observation site (see Table 2 for decision tree details); however, there is a low level of confidence in the ability of the CO_2 technique to determine whether the radiances from the remaining FOVs actually represent low clouds (not reported in the SCP) or very thin mid/high clouds. Therefore, the MCLR category is used to indicate the possible presence of very thin, transparent clouds whenever total sky coverage and cloud top heights are difficult to accurately estimate. While the MCLR report is placed in the MID column of the SCP, the very thin clouds may be at **any** altitude above 631 mb. The heights in the CLD TOP column should be used with discretion during MCLR conditions.

Third, an average ECA for the observation site is determined by averaging the individual ECAs from the 25 FOVs around the observation site. If a low cloud is indicated for a particular FOV, the ECA for that FOV is considered zero in the calculation. The value given in the SCP is the **average ECA** and is expressed in percent. Occasionally, the average ECA will be reported as zero when clouds are being reported. This is due to the average ECA being less than 0.5%.

5. TESTS AND RESULTS

5a. Complemented ASOS Observations vs. Manual Observations

During the 28 day period from March 16, 1992, through April 13, 1992, Unger (1992) studied complementary satellite cloud data for 58 stations in the United States (Figure 4). Manual (human) observations were compared with "ASOS observations" that had been complemented with satellite cloud data. Since official ASOS data were not yet available from these sites, the manual observations were used to create "simulated ASOS" observations. Simulated ASOS observations included only data in the manual observations up to 12,000 feet AGL. The fact that true ASOS observations were not tested was not critical to this analysis, since the objective was to assess agreement between satellite and manual observations for clouds above 12,000 feet MSL. Hereafter, the simulated ASOS observations will be referred to as ASOS observations. ASOS observations with complemented satellite data will be referred to as ASOS/SAT observations.

Comparisons of total cloud cover were conducted on a categorical basis. Table 3a shows a comparison between ASOS/SAT observations and manual observations. Since the human eye is more capable of observing clouds during the day than at night, the quality of manual observations varies with time of day. Therefore, daytime (1500-2200 UTC) and nighttime (0300-1000 UTC) stratification are given in Tables 3b and 3c, respectively.

In Tables 3a, 3b, and 3c, the agreement between manual and ASOS/SAT observations for each category lies along the diagonal. For all categories combined, agreement occurred 69% of the time (70% during the day and 68% at night). When clear, scattered, broken, and overcast conditions were observed by the manual observer, the relative percentages of agreement with ASOS/SAT (all times of day) were 77, 52, 31, and 93, respectively. During the day, these relative percentages of agreement were 77, 60, 34, and 93, respectively; at night they were 76, 46, 30, and 94. Compared to the manual observations, the ASOS/SAT observations tended to favor the extremes (clear or overcast), with fewer cases in the intermediate categories (scattered or broken). In a different study, Schreiner et al. (1993) noticed this same pattern, and noted that it may have been caused by the relatively large FOVs (10 km at mid-latitudes). This probably made the resolution of small cloud masses or small cloud breaks difficult. This was especially noteworthy whenever ASOS/SAT estimated broken conditions as overcast. When analyzing these data for single category discrepancies, it is important to note that the distinction between scattered and broken clouds may involve a considerable amount of human subjectivity. Considering the definitions of these cloud coverage terms, even the distinctions between clear/scattered and broken/overcast are somewhat subjective. Consequently, a single category difference may not always represent a substantial discrepancy, but two-category differences nearly always do.

		CLR	SCT	BKN	OVC	Total
		ASOS/SAT OBSERVATIONS				
MANUAL OBSERVATIONS	CLR	2931	588	54	230	3803
	SCT	662	1510	158	600	2930
	BKN	211	424	886	1292	2813
	OVC	77	132	141	4697	5047
	Total	3881	2654	1239	6819	14593

Table 3a. Contingency table for the ASOS/SAT vs. manual observations at 58 locations in the United States during the period March 16 - April 13, 1992 (all times of day).

		CLR	SCT	BKN	OVC	Total
		ASOS/SAT OBSERVATIONS				
MANUAL OBSERVATIONS	CLR	954	266	5	15	1240
	SCT	247	704	75	150	1176
	BKN	70	227	432	552	1281
	OVC	24	59	64	1951	2098
	Total	1295	1256	576	2668	5795

Table 3b. Same as Table 3a, except for daytime occurrences (1500-2200 UTC) only.

		CLR	SCT	BKN	OVC	Total
		ASOS/SAT OBSERVATIONS				
MANUAL OBSERVATIONS	CLR	1211	222	30	131	1594
	SCT	249	457	48	248	1002
	BKN	64	105	249	415	833
	OVC	25	32	40	1472	1569
	Total	1549	816	367	2266	4998

Table 3c. Same as Table 3a, except for nighttime occurrences (0300-1000 UTC) only.

5b. Cloud Opacity

An attempt was also made to evaluate the possibility of using the satellite-cloud technique to differentiate between thin and opaque clouds. To avoid considering cases where one category differences between ASOS/SAT and manual observations may have been subjective, only two category differences were considered. The manual observations were interpreted in two distinct ways (TOTAL and OPAQUE sky cover). For TOTAL sky cover, each manual observation was interpreted as reported in the SAO. For OPAQUE sky cover, the top layer of clouds in the manual observation was ignored when reported as thin. For example, consider the manual observation 140 SCT 250 -OVC. For the determination of TOTAL sky cover, this observation would be considered overcast. However, for OPAQUE sky cover, the top thin layer would be ignored, making the OPAQUE sky cover scattered. On the other hand, the manual observation 140 SCT E250 OVC would yield an overcast OPAQUE sky cover, since the cirrus deck was not reported as thin.

Table 4 gives the percentage of two-category discrepancies between ASOS/SAT and manual observations (considering both the TOTAL and OPAQUE definitions of sky cover in the manual observation). The data were stratified by day (1500 to 2200 UTC) and night (0300 to 1000 UTC). The "underestimated" column refers to the percentage of time that the ASOS/SAT system underestimated the manually observed cloud cover by two or more categories. The "overestimated" column refers to the percentage of time that the ASOS/SAT system overestimated the manual cloud observation by two or more categories.

Sky cover	Underestimated	Overestimated
OPAQUE		
Day	1	10
Night	1	13
TOTAL		
Day	3	3
Night	2	8

Table 4. Percentage of time that a two-category discrepancy was noted between ASOS/SAT observations and manual observations. Both OPAQUE and TOTAL sky cover, as defined in the text, were considered. The data were stratified into day and night. The total sample size was 5801 cases.

Most noteworthy in the table is the tendency of ASOS/SAT observations to overestimate OPAQUE sky cover at all times of the day. No bias in either direction (overestimation or underestimation) occurs for the ASOS/SAT estimate of TOTAL sky cover, thus one can assume that ASOS/SAT estimates TOTAL sky cover (which includes thin clouds) better than OPAQUE sky cover. At night, however, ASOS/SAT showed a bias toward overestimation. Considering that TOTAL sky cover is a human measurement, and that the human eye has trouble discerning high, thin clouds at night, it seems reasonable to assume that ASOS/SAT is not really overestimating the TOTAL sky cover, but simply measuring something that the manual (human) observation is not detecting. This presents a dilemma. The satellite cloud cover algorithm seems more effective at estimating TOTAL sky cover than OPAQUE sky cover. Yet, OPAQUE sky cover is often considered more significant operationally, since high-thin clouds transmit more light than opaque clouds.

An attempt was made to estimate cloud opacity from the average ECA in the SCP, since average ECA depends on total cloud cover and cloud transparency. If the average ECA was low (less than 0.66), and the satellite sky cover algorithm still indicated overcast conditions, the overcast deck was assumed to be thin. The 0.66 value was selected based upon qualitative comparisons of satellite and human observations. For broken conditions, the highest average ECA required to indicate thin clouds was assumed to be about half that of an overcast and set to 0.33. This assumption was made because the radiance contributions of some FOVs would be from clear columns below the cloud breaks. From these FOVs, the ECA contributions to the average ECA would each be zero. No attempt was made to distinguish thin from opaque scattered clouds. It is important to note that the cutoff values used to distinguish thin clouds were subjectively estimated here, since only one month of data were used to obtain these results. It is possible that the ECA cutoff values that best distinguish thin from opaque clouds may be slightly different than these values. The results from the satellite estimates of OPAQUE clouds, using the average ECA, are given in Table 5.

Sky cover	Underestimated	Overestimated
OPAQUE		
Day	2	5
Night	2	6

Table 5. Similar to Table 4 for OPAQUE conditions (as defined earlier in the text), except the average ECA adjustment was applied to the satellite cloud algorithm.

These results indicate less of a discrepancy between the ASOS/SAT observations and the opaque manual observations, whenever the average ECA was used to adjust the satellite estimates of opaque cloud cover. While some overestimation of opaque conditions still resulted, the number of overestimates was cut to less than half the number (5-6%) that resulted when the average ECA was not used (10-13%).

6. SUMMARY

The SCP is a new data source that complements ASOS surface observations with satellite-derived cloud data above 631 mb. In general, radiances from the VAS sounder are collected between 20 and 30 minutes past each hour, the CO_2 absorption technique is used to estimate various cloud parameters, and the final product is ready for transmission by 55 minutes past each hour. Due to competing operational schedules, there are some exceptions to this availability time.

The NCDC, in Asheville, North Carolina, receives satellite FOV observations on a daily basis from Camp Springs, Maryland, where the technique is run. Following receipt at NCDC, the FOV data are quality controlled, used in producing the LCD publication, and archived.

The strengths of the SCP are:

- It complements ASOS with cloud data above the 631 mb pressure level (approximately 12,000 feet MSL).
- Data are generally available hourly.
- As the GOES-8-J system becomes operational, data will be available across the contiguous United States except for portions of North Dakota and Montana.
- It may help in the detection of high clouds at night.
- The average ECA values in the report can assist in estimating cloud opacity (a difficult estimation to make at night with either the human eye or satellite imagery).

The weaknesses of the SCP are:

- At press time, cloud estimates were not available over the northeast United States from GOES-7.
- The technique is generally capable of detecting only the highest cloud layer. Individual tops of multi-layered clouds are not resolved. In the case of two layers of clouds, with the top layer being thin, the reported cloud top height will likely be a level between the two layers.
- Sometimes, very thin clouds (usually cirrus) either go undetected or are misidentified as low clouds. Hence, clouds with low tops (at or below 631 mb) are not reported. Whenever there is sufficient doubt about whether the radiances above a station represent low clouds or higher thin clouds, the sky cover for that station is designated MCLR.
- Whenever thin clouds are present, the cloud top height estimates should be used judiciously. This is especially true when the technique estimates MCLR conditions.

- A strong surface-based inversion (i.e., within an Arctic air mass) may result in a report of middle clouds when skies are actually clear.

- Horizontal resolution averages 10 km in the mid-latitudes. Hence, the technique tends not to resolve small cloud masses and small cloud breaks.

7. ACKNOWLEDGEMENTS

The authors wish to thank the following individuals for their work on this project: Jackson Pellett (Office of Meteorology) for his many hours of work in coordinating all aspects of the SCP project; David Mannarano (Office of Systems Development) and Marjorie McGuirk (formerly of the Office of Systems Development) for their efforts in the initial development and early evaluation of the project; Paul Menzel (University of Wisconsin) for his work on the development of the CO_2 slicing technique; Steve Ambrose (NESDIS) for his work on the initial evaluation and coordination of the daily file format; Gary Ellrod (NESDIS) for his efforts on running and testing the technique on the VAS Data Utilization Center (VDUC); J. Paul Dallavalle (Techniques Development Laboratory) for his work testing and evaluating the data; Steve Evans (NCDC) for integrating the SCP data into the LCD publication; Glenn Rutledge (formerly of NESDIS, currently with the Office of Meteorology) for his work on the operational implementation of the product; Ken Snowden and Bill Godfrey (Planning Research Corporation) for their programming efforts; and Warren Sunkel and Bill Fortune (Central Region Headquarters) for their efforts on the spring 1992 evaluation.

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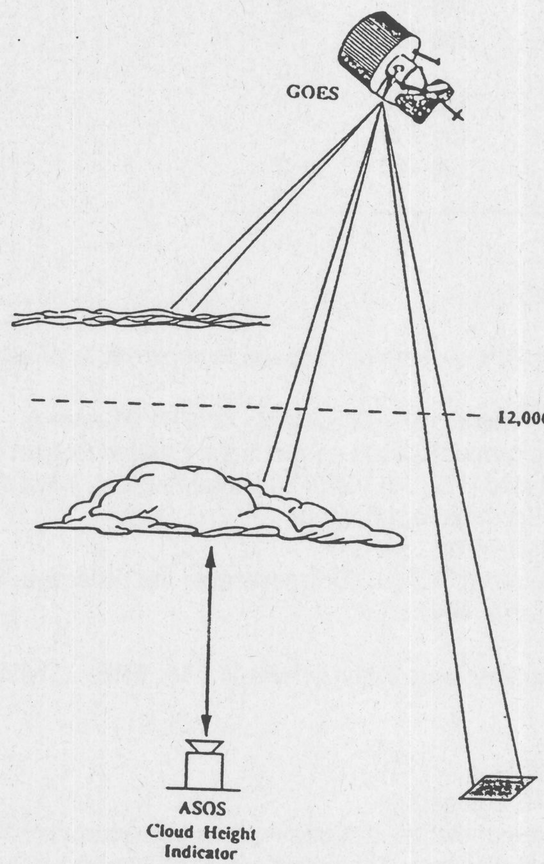

Figure 1. The ASOS Cloud Height Indicator cannot detect clouds higher than 12,000 ft AGL. The GOES satellite can observe the tops of clouds at all levels, and can estimate the cloud top height and fractional cloud cover by means of multispectral techniques. In order to do this, radiance measurements from clear sky regions must also be obtained.

NMCSCPER1
TBUS20 KWBC 181841
SATELLITE-DERIVED CLOUD INFORMATION FOR MID (CLD TOPS 631-400 MB)
AND HIGH LEVEL (CLD TOPS ABOVE 400 MB)
(SEP)

STA	DA/TIMEZ	MID	HIGH	CLD TOP	ECA
ACY	18/1823		OVC	280-440	93
CHS	18/1825	SCT	SCT	120-330	27
CLT	18/1824	SCT	SCT	210-380	1
DAY	18/1823	CLR			0
IAD	18/1823	SCT		150-230	7
PIT	18/1823	SCT		150-210	8
ROA	18/1824	MCLR		120-200	3

The following is a description of each line:

Line 1. AFOS Header (displayed for AFOS users only). Sample shown is the Eastern Region collective (xxx = ER1);
Also available: xxx = CR1 (Central), SR1 (Southern), or WR1 (Western)

Line 2. WMO Header and date/time group. Sample shown is the Eastern Region collective (TBUS20 KWBC); Also available: TBUS21 KWBC (Central Region), TBUS22 KWBC (Southern Region), or TBUS23 (Western Region)
dd = Date of month (i.e. 01,02,...,30,31)
hhmm = hour and minute (UTC) NESDIS generated the collective. Sample shown was generated at 1841 UTC.

Lines 3-4. Title of product

Line 5. Month during which observations were taken (mmm = JAN, FEB, ..., NOV, DEC). Sample shown is from September.

Line 6. Table Header line

Lines 7-end. Parameters for each station:
a) STA: Station id (1 - 5 characters)
b) DA/TIMEZ: Date/time of the satellite observation in the format dd/hhmm (UTC)
c) MID: Mid-level cloud coverage (for clouds between 631 and 400 mb [approximately 12,000-23,600 ft MSL]).
d) HIGH: High level cloud coverage (for clouds above 400 mb [approximately 23,600 ft MSL]).
e) CLD TOP: Heights of lowest and highest cloud tops (hundreds of ft MSL), as seen by the satellite in a 50 x 50 km box centered on the station.
f) ECA: Average effective cloud amount (ECA) in percent. ECA is a function of cloud top coverage and emissivity.

Figure 2. Sample Eastern Region satellite-derived cloud cover product (SCP) collective for September 18, 1993 at 1841 UTC. Generic decoding information is also explained below the sample product.

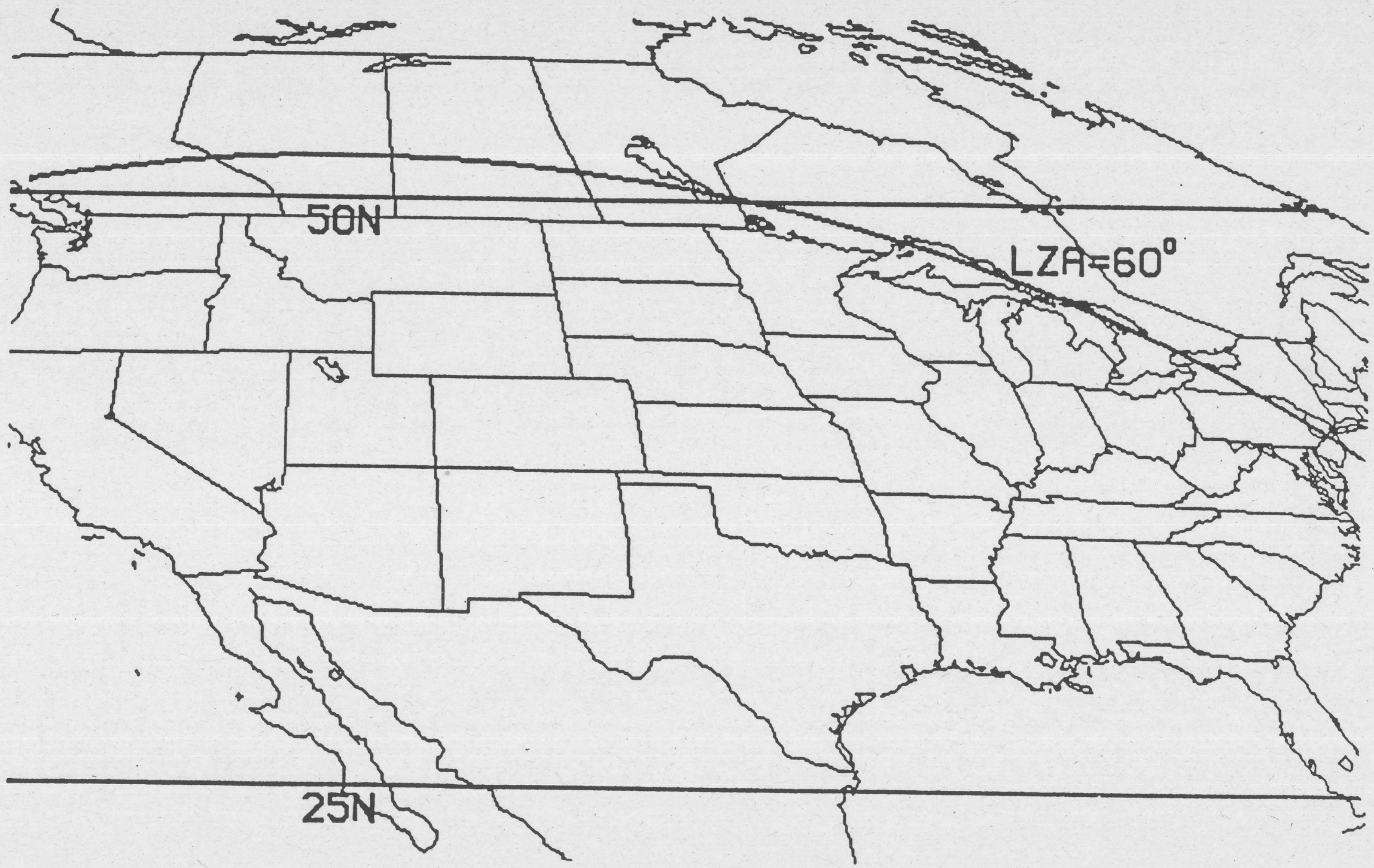

Figure 3. Area of cloud information provided by GOES-7 stationed at 112°W.

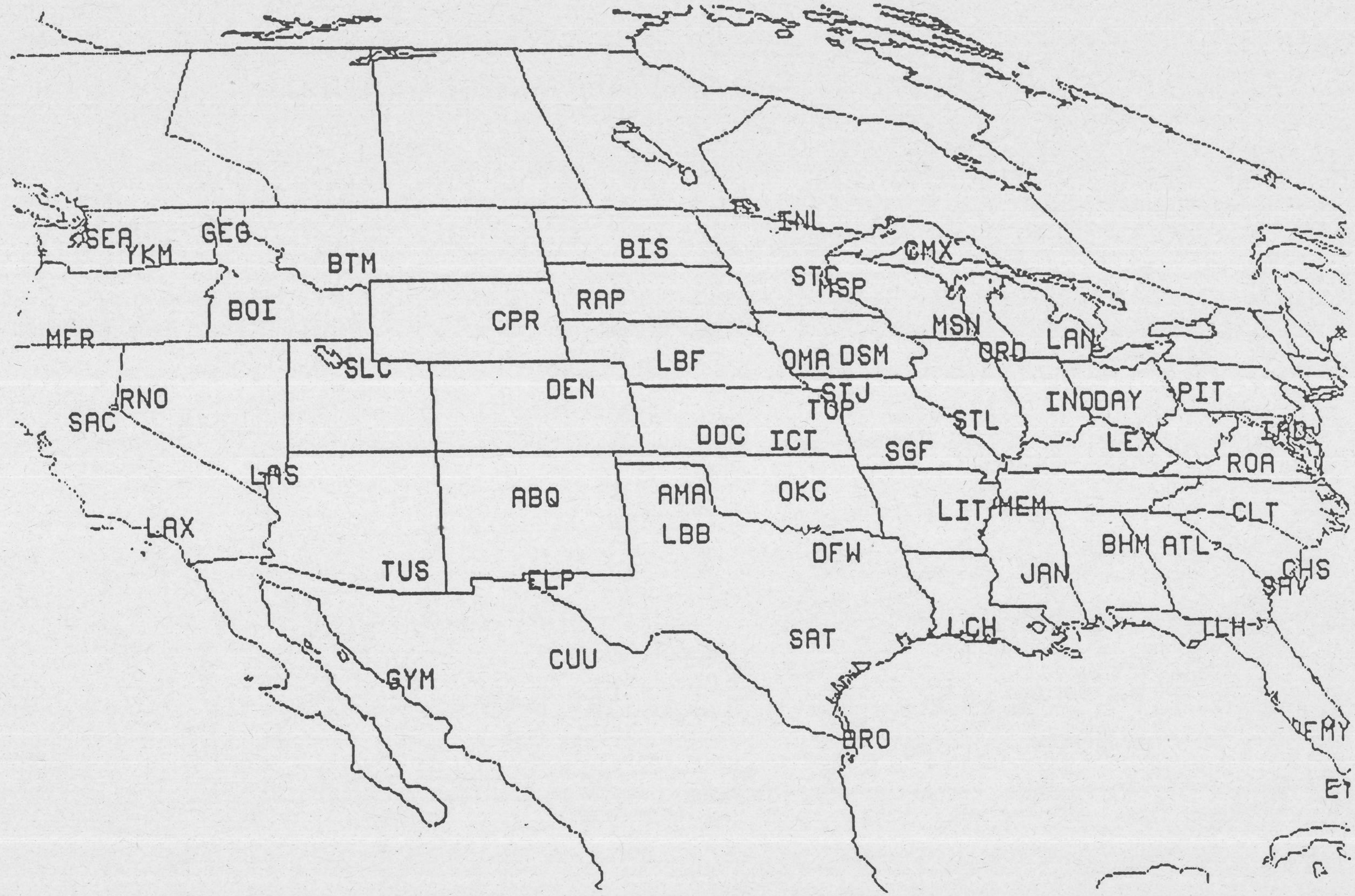

Figure 4. Station locations used in the March 16 - April 13, 1992 comparison test.

APPENDIX

TABLE OF ACRONYMS

AFOS	Automation of Field Operations and Services
AGL	Above Ground Level
ASOS	Automated Surface Observing System
ASOS/SAT	ASOS data complemented with SATellite cloud data
BKN	Broken
CIMSS	Cooperative Institute for Meteorological Satellite Studies
CLR	Clear
CTP	Cloud top pressure
ECA	Effective cloud amount
FOV	Field-of-view
GOES	Geostationary Orbital Environmental Satellite
IR	Infrared
LCD	Local Climatological Data
LZA	Local Zenith Angle
MCLR	Mostly clear
MSL	Mean Sea level
NCDC	National Climatic Data Center
NESDIS	National Environmental Satellite, Data, and Information Service
NGM	Nested Grid Model
NOAA	National Oceanic and Atmospheric Administration
NMC	National Meteorological Center
NWS	National Weather Service
POES	Polar-Orbitting Environmental Satellite
OFCM	Office of the Federal Coordinator for Meteorological Services and Supporting Research
OVC	Overcast
RISOP	Rapid Imaging Satellite OPerations
SAO	Surface Aviation Observation
SCP	Satellite-derived cloud cover product
SCT	Scattered
UTC	Coordinated Universal Time
VDUC	VAS Data Utilization Center
VAS	Visible Infrared Spin-Scan Radiometer (VISSR) Atmospheric Sounder
WMO	World Meteorological Organization