NOAA Technical Memorandum NESDIS 29

PRELIMINARY REPORT ON THE DEMONSTRATION OF THE VAS CO_2 CLOUD PARAMETERS (COVER, HEIGHT, AND AMOUNT) IN SUPPORT OF ASOS

Washington, D.C.
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UNITED STATES DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Environmental Satellite, Data, and Information Service

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W. P. Menzel
Office of Research and Applications
and
K. I. Strabala
University of Wisconsin
CIMSS

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UNITED STATES
DEPARTMENT OF COMMERCE
Robert A. Mosbacher, Secretary

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National Environmental Satellite,
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Thomas N. Pyke, Jr.
Assistant Administrator

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K. I. Strabala
UW/CIMSS

1. Introduction

As part of its modernization plan, the National Weather Service is implementing an Automated Surface Observing System (ASOS) which uses automated equipment to provide surface weather data that are currently obtained by NWS observers. Since the cloud information from the ASOS equipment is confined to below 12,000 feet, the satellite has been suggested as a source of supplemental information so that the combined ASOS/satellite system can depict cloud conditions at all levels. Because observations are desired every hour, the satellite cloud product must be derived from the geostationary spacecraft data.

A demonstration of the utility of VAS (Visible Infrared Spin Scan Radiometer Atmospheric Sounder) CO_2 cloud parameters (cover, height, amount) for augmenting conventional ground observations has been undertaken. The geostationary multispectral observations are readily synchronized with the ground reports and are available over North America. Three weeks of comparisons in summer 1989 of the satellite derived cloud information with surface observations show that the satellite can supplement surface measurements of cloud cover above 10,000 feet. Preliminary conclusions are that (a) above 400 mb (25,000 feet) the satellite information is more reliable, (b) between 400 and 700 mb (10,000 feet) the satellite and ground observations are complementary, (c) below 700 mb the surface observation is preferable.

This report explains the VAS cloud product derivation, presents a few illustrative examples, summarizes the statistics of the three weeks of intercomparisons, and suggests guidelines for interpreting the satellite results.

2. Technique Description for Satellite (VAS) Cloud Products

The CO_2 technique calculates both cloud top pressure and effective amount from radiative transfer principles; it also reliably separates transmissive clouds that are partially transparent to terrestrial radiation from opaque clouds in the statistics of cloud cover (Wylie and Menzel, 1989). The CO_2 algorithm has been described in the literature (Chahine, 1974; Smith et al., 1974; Smith and Platt, 1978; Menzel et al., 1983) and its application to data from the GOES/VAS has been published (Wylie and Menzel, 1989). The technique description and its application will only be briefly presented here; more detail is available in the cited references.

The VAS radiometer measures infrared radiation in three spectral channels in the CO_2 absorption band near 15 microns and in the infrared window near 11 microns at 7 to 10 km resolution (depending upon viewing angle). The three channels in the CO_2 absorption band are used to differentiate cloud altitudes and the longwave infrared window channel identifies the effective fractional cloud cover in the VAS field of view (FOV).

To assign a cloud top pressure to a given cloud element, the differences in cloud produced radiances, $I(\nu)$, and the corresponding clear air radiances, $I_{cl}(\nu)$, for two spectral channels of frequency ν_1 and ν_2 viewing the same field-of-view are written as a ratio

$$\frac{I(\nu_1) - I_{cl}(\nu_1)}{I(\nu_2) - I_{cl}(\nu_2)} = \frac{\epsilon_1 \int_{P_s}^{P_c} \tau(\nu_1,p) \frac{dB[\nu_1, T(p)]}{dp} dp}{\epsilon_2 \int_{P_s}^{P_c} \tau(\nu_2,p) \frac{dB[\nu_2, T(p)]}{dp} dp} . \qquad (1)$$

In this equation, ϵ is the cloud emissivity, P_s the surface pressure, P_c the cloud pressure, $\tau(\nu,p)$ the fractional transmittance for radiation of frequency ν emitted from the atmospheric pressure level (p) arriving at the top of the atmosphere (p=0), T(p) is the atmospheric temperature profile, and $B[\nu,T(p)]$ is the Planck radiance of frequency ν for temperature T(p). If the frequencies are close enough together, then ϵ_1 approximates ϵ_2, and one has an expression by which the pressure of the cloud within the FOV can be specified. The left side of Equation (1) is determined from the VAS observed radiances in a given FOV and clear air radiances provided from spatial analyses of VAS clear sky radiance observations. The right side of Equation (1) is calculated for a range of cloud top pressures, P_c (1,000 to 100 mb is spanned by discrete values at 50 mb intervals), using representative profiles of temperature and atmospheric transmittance. In this study, analyses of temperature and moisture fields from the National Meteorological Center (NMC) are used. Transmittances are determined from line-by-line calculations using the appropriate VAS spectral response functions. The optimum cloud top pressure is determined when the calculated ratio on the right side of Equation (1) comes closest to equaling the measured ratio on the left side of Equation (1). This expression assumes the presence of only one cloud layer for a given FOV; when multiple layers are sensed, it derives a cloud altitude in between the altitude of the two separate layers.

Once a cloud height has been determined, the effective fractional cloud cover for the FOV (also referred to as effective cloud amount in the literature) can be evaluated from the infrared window channel data using the relation

$$N\epsilon = \frac{I(w) - I_{cl}(w)}{B[w, T(P_c)] - I_{cl}(w)} . \quad (2)$$

Here N is the fraction of cloud cover within the FOV, $N\epsilon$ the effective fractional cloud cover, w represents the window channel frequency, and $B[w, T(p_c)]$ is the opaque cloud radiance.

If no ratio of radiances can be reliably calculated because $(I-I_{cl})$ is within the instrument noise level, then a cloud top pressure is calculated directly from the comparison of the VAS observed 11.2 micron infrared window channel brightness temperature with an in situ temperature profile and the effective fractional cloud cover is assumed to be unity. This occurs about 20% of the time, primarily for low clouds below 700 mb, where the CO_2 weighting functions do not have adequate sensitivity. In this way, all clouds are assigned a cloud top pressure either by CO_2 or infrared window calculations.

Fields of view are determined to be clear or cloudy through inspection of the 11.2 micron brightness temperature with a split window correction for moisture absorption. If the moisture corrected 11.2 micron brightness temperature is within 2 degrees Kelvin of the known surface temperature (which is taken from the 1,000 mb NMC model analysis adjusted with hourly observations from the surface network), then the FOV is assumed to be clear and no cloud parameters are calculated.

In the study of Wylie and Menzel (1989), the CO_2 cloud heights derived from VAS (VISSR Atmospheric Sounder) data over North America were found to be of good quality when compared to three other independent sources of cloud height information. Results showed: (a) for about thirty different clouds, the CO_2 heights were within 40 mb rms of radiosonde moisture profiles; (b) in 100 comparisons with lidar scans of clouds, the CO_2 heights were 70 mb lower on the average and were within 80 mb rms; (c) satellite stereo parallax measurements in 100 clouds compared to within 40 mb rms. The CO_2 heights appeared to be consistent with other measurements within 50 mb and the effective fractional cloud cover within 0.20 in most cloud types (broken clouds and stratocumulus at low levels remain elusive). In that study, two years of VAS cloud parameter determinations revealed reasonably good agreement with the manual weather observations of Warren et al. (1986).

In this study the CO_2 technique was applied to data from the infrared window centered at 11.2 microns and the CO_2 bands centered at 13.3, 14.0, and 14.2 microns. Radiances for each FOV were processed to estimate cloud height and cover (representing an area of roughly 10 km by 10 km at mid-latitudes). For a selected site, the nearby twenty FOVs were processed individually. The comparison between satellite and ground cloud determinations is performed in the following way. The satellite cloud height and amount determinations for the twenty FOVs over the site of the ground observation were statistically segmented. Effective cloud amounts are grouped from 0 to .33, .33 to .66, .66 to .95, and .95 to 1.0; likewise, the cloud heights are grouped from 1000 to 700, 700 to 400, and 400 to 0 mb. The histograms of satellite determinations are investigated for patterns that can reveal the ground observation.

3. Specific Examples

Several examples show that the satellite can successfully distinguish cloud versus no cloud, can see multi-layers above those observed from ground, and often provides important data when the ground observers view is obstructed (by night, fog, low cloud cover, blowing dust, ...).

Figure 1 (and Table 1) show examples where ground and satellite observations supplement each other. In multiple cloud layers, Manhattan, Kansas (MHK) reports at 2200 UT on 22 June 1989 light rain showers, broken cloud at 2700 feet, broken cloud at 4,000 feet, and overcast skies at 7,000 feet. The satellite reports 30% cirrus higher than 400 mb with 25% cirrus and 45% opaque cloud between 400 and 700 mb. Both observations are compatible. Under a large convective cloud deck, Dodge City, Kansas (DDC) reports rain and fog, broken (greater than 50% cover) cloud at 200 feet, and overcast skies at 5500 feet. The VAS reports 20% transmissive and 80% opaque cloud above 400 mb. Again, both observations are compatible. The satellite view to ground is obstructed by opaque clouds, while the ground observers view to higher clouds is obstructed by rain, fog, and low lying opaque clouds. In circumstances such as these, a simple estimation of the opaque cloud thickness could be made from the difference in the height of the lowest layer the satellite observes and the height of the overcast layer the ground observer views. This information would be useful, especially to the airlines, for evaluating the strength of the convective cloud systems. In this example, the cloud thickness would be estimated in excess of 20,000 feet. Under scattered (less than 50% cover) clouds, North Platte, Nebraska (LBF) reports scattered cloud at 3,000 feet and also at 10,000 feet. The satellite reports 45% thin transmissive cloud above 400 mb, 5% thin transmissive cloud between 400 and 700 mb, 25% opaque cloud below 700 mb, and 25% clear skies. Again, the satellite view seems to be supplementing the surface observation.

Figure 2 presents an example of the satellites ability to discern mature cumulonimbus clouds in the infrared window image. At 1400 UT on 27 June 1989, Cleveland, Ohio (CLE), reports a light thundershower under low (1300 feet) overcast clouds. The satellite shows 100% opaque clouds above 400 mb (Table 2), strongly suggesting that convective precipitation is occurring below. (see section 5 for further discussion).

To illustrate how the ground observer's view can be obscured by means of fog, haze, precipitation, etc. (and by darkness), Figure 3 shows the satellite infrared window view over Phoenix, Arizona at 0600 UT (11:00 pm local time) on 29 July 1989. The ground observer reports clear skies, whereas the satellite senses high to middle overcast clouds (Table 3). The night viewing capability of the satellite infrared sensor is a valuable asset to the ground observer after sunset, since the infrared measurements are independent of sunlight amount and remain consistent throughout diurnal changes.

VAS cloud height estimates have proven to be consistent with ground based observations in two layer cloud systems. Figure 4 presents a GOES-7 infrared window image from 1700 UT on 13 September 1989 (see also Table 4). Low clouds cover a broad region from Illinois, west though Kansas into Colorado, overlaid by a cirrus shield from Oklahoma to Michigan. In the low clouds Grand Island, Nebraska (GRI), reports a 1700 UT observation of overcast clouds at 2900 feet. The VAS reports 35% transmissive cloud above 400 mb, 5% transmissive from 400-700 mb, and 60% cloud below 700 mb. Low clouds dominate the satellite observation, although thin cirrus is sensed above. In the high clouds at the northern fringe of the low cloud deck, Des Moines, Iowa (DSM), reports scattered at 2,000 feet and overcast at 25,000 feet. Collocated satellite data reports 80% transmissive clouds above 400 mb, and 20% transmissive clouds from 400-700 mb. Cirrus clouds dominate the DSM ground observation, which is consistent with the transmissive high clouds sensed by the satellite. In the overlap region of the two cloud systems at Kansas City, Missouri (MCI), the 1700 UT observation, with light rain and fog, indicates scattered at 800 feet and overcast at 2700 feet. The VAS reports 30% transmissive above 400 mb and 70% opaque above 400 mb. The ground observers upward view is limited by low clouds, rain, and fog. Conversely, the satellites downward view ends at the highest level cloud deck. Based on the agreement of the cloud parameters evaluated by both methods at DSM and GRI, both observations at MCI can be assumed correct. This example shows that the high clouds reported by the satellite are credible, even though the ground observer cannot see them.

Correct navigation of satellite images are crucial to the evaluation of VAS cloud parameters in the context of supporting ASOS. Examples have been found (not shown) where the image is offset by as much as four FOVs (roughly 40 km). It is apparent that errors of this magnitude can lead to significant discrepancies. The satellite can supplement ASOS only if the navigation is maintained at its usual high standard (less than 2 km error).

4. Intercomparison Statistics

Tables 5 through 9 present the average satellite response to given ground characterizations of the cloud cover and weather for three separate weeks in July, August, and September 1989. The averaged satellite derived parameters readily distinguish clear from cloudy conditions. In addition, they exhibit features which can be used to recognize overcast clouds at all levels, determine the presence of rain and thundershowers, and differentiate scattered from broken cloud conditions in mid to high clouds. Less pronounced signatures occur with multi-layer clouds.

Table 5 contains the results for surface observations of totally clear sky. The satellite agrees 77% of the time. High or middle level clouds in 6% of the observations are probably real, missed by the ground observer. 17% of the observations are classified as low opaque cloud, representing FOVs where the CO_2 technique failed and a window channel determination was made. In the study of Wylie and Menzel (1989), it was found that one fifth of these reports can be associated with very thin clouds. These 4% percent representing thin high clouds were likely missed by the ground observer also. The remaining 13% are failures to distinguish ground from cloud in the presence of low level inversions. Thus, in about 10% of the disagreements, the satellite is probably correct; in about 13%, the satellite is probably wrong. It is interesting to note that the percentage of disagreement increases with nightfall (from 20% to 40%), when the ground observations are impaired by darkness.

Histograms of satellite derived cloud parameters concurrent with ground observed single layer overcast indicate dominance in 400 mb and above sensed clouds. This occurs for observed low (less than 10,000 feet), middle (between 10,000 and 25,000 feet) and high clouds (greater than 25,000 feet). The discrepancies between satellite and ground height estimates are mainly due to daily summer development of thick convective clouds. The satellite views cloud tops, while the observer sees cloud bases. Tables 6a-6c show that satellite cloud amount determinations above 400 mb tend to increase (from 56% to 68% to 82%) as ground observations of the height of the overcast skies increase. Clear skies totalled 5% or less for each category. By providing information on clouds aloft (above 700 mb), the satellite supplements the ground cloud observations 78% of the time when low overcast are restricting the ground view. This is important in aviation considerations.

The CO_2 technique also demonstrates the capability to distinguish scattered (ground observer sees less than 50% cloud cover) from broken (greater than 50% is seen) clouds above 700 mb. Tables 7a-7d present satellite results when ground observes scattered and broken single layer clouds at mid and high levels. Satellite determinations of clear skies decrease roughly by a factor of three when the ground observations go from scattered to broken, in both mid (48% goes to 17%) and high (65% goes to 25%) observed clouds. In addition, the observations of effective cloud amount between .33 and .66 are greater than 10% when it is broken cloud and less than 10% when it is scattered cloud. Thus, a differentiation between scattered and broken clouds seems to be that broken clouds occur when more than 10% of the satellite observations have effective cloud amount between .33 and .66 and less than 25% of the satellite observations find clear sky; when these two conditions are both invalid the ground observer usually reports scattered cloud cover.

Tables 8a-8c present statistics for three different cloud layer combinations; low/mid, low/high and mid/high. The averaged parameters are very similar for all three sets of multi-layer clouds, with the statistics dominated by clouds sensed above 400 mb. It is difficult to distinguish multi-layer clouds versus broken decks with the satellite. Often they indicate the same condition in the atmosphere.

Cold cumulonimbus cloud tops can be readily sensed by the CO_2 technique. Results for ground observed precipitation and thundershowers (Table 9) show 32% opaque clouds above 400 mb and only 2% below 700 mb. Opaque observations in more than 25% of the FOVs can serve as an indicator of surface observed precipitation.

These statistics seem to support the claim that satellite derived cloud parameters can be used to effectively supplement ground observations of cloud amount, cloud height, and convection. The task remains to convert the satellite histogram of observations over one site into cloud cover classifications familiar to the ground observer.

5. Guidelines for Interpreting the Satellite Data

Table 10 shows a template for a typical histogram from the satellite cloud parameter determinations for the twenty FOVs over a selected ground site. An x has been used to indicate where the satellite does not provide additional information. The percentage of clear sky observations is denoted by a; high clouds have the subscript 1, and middle level clouds have the subscript 2. The failures of the satellite technique accumulate as low opaque clouds and thus are incorrectly added to f. The satellite information is reliable in clear skies and for middle to high level clouds.

The following preliminary guidelines are suggested for interpretation of the satellite data. Let S1 indicate the sum of the terms in the first row of the template, and similarly S2 the second row..

a. Precipitation usually occurs if $e1 > 25$

b. Overcast conditions are associated with $a < 7$
Overcast with high cloud if $S2 < S1$
Overcast at middle levels if $S2 > S1$

c. Broken clouds are indicated by $7 < a < 25$
and $c1 + c2 > 10$
High clouds if $S2 < 10$
Middle level clouds if $S2 > 10$

d. Scattered clouds are indicated by $25 < a < 70$
and $c1 + c2 < 10$
High clouds if $S2 < 5$
Middle level clouds if $S2 > 5$

e. Low opaque cloud cover is indicated by $f > 40$

f. Clear skies can be associated with $a > 70$

The satellite has difficulty resolving low clouds; however, when the temperature difference between the ground and low in the atmosphere is large enough (greater than 2 K) some low clouds are correctly identified. All of these clouds are classified as opaque (low broken or scattered clouds are not possible satellite classifications). Thus f includes correct identification of low opaque clouds plus errors from underestimation of thin transmissive clouds, window channel evaluation of ground as low cloud, and misidentification of broken or scattered low clouds as opaque. These inaccuracies make ground observations preferable below 10,000 feet.

However above 10,000 feet, the satellite clearly supplements the ground observation. As Table 6a indicates, when the ground observer is limited by low overcast conditions, the satellite provides additional information about upper level clouds 80% of the time.

A preliminary test of the template was performed with satellite and ground observations of 22 and 23 September 1989. These days presented a variety of cloud types and cloud amounts, so that different synoptic conditions are well represented. Verification categories were divided as follows: instances where the ground and satellite observations agreed; instances were the ground and satellite observations disagreed, but both were probably correct; and instances where the ground and satellite observations disagreed, and the satellite was incorrect. Results show 54% (72 of 133) of the VAS derived cloud observations agreed with the ground observations. Another 25% show disagreement with both being correct. 21% (28 of 133 of the satellite observations disagreed and were assumed incorrect. Several of the disagreements involved characterization of broken as overcast clouds. Falsely identifying ground as low cloud also accounted for a few of the satellite mistakes. In this one instance, the template appears to be functioning reasonably well; there is corroborating or complementary information 79% of the time.

6. Conclusions

The CO_2 method for calculating cloud parameters (height and amount) has produced good results with VAS radiances. The satellite and ground observer reports of cloudiness complement each other; the satellite does better at high levels (above 400 mb), while the ground observer is more reliable at low levels (below 700 mb). The satellite can definitely supplement the ASOS with cloud information above 12,000 feet.

7. Acknowledgements

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TABLE 1

INTERCOMPARISON OF SATELLITE AND GROUND OBSERVATIONS OF CLOUD COVER FOR 2200 UT 22 JUNE 1989

AT MANHATTAN, KANSAS (MHK)

Satellite

Cloud Top Pressure	Effective Cloud Amount < 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	0	15	15	0
400 - 700	0	0	25	45
PCT > 700	0	0	0	0
PCT = 1000	0	0	0	0

Ground

Station Reports Rain Showers
Broken Clouds at 2700 feet
Broken Clouds at 4000 feet
Overcast at 7000 feet

AT DODGE CITY, KANSAS (DDC)

Satellite

Cloud Top Pressure	Effective Cloud Amount < 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	0	0	20	80
400 - 700	0	0	0	0
PCT > 700	0	0	0	0
PCT = 1000	0	0	0	0

Ground

Station Reports Rain Showers and Fog
Broken Clouds at 200 feet
Overcast at 5500 feet

AT NORTH PLATTE, NEBRASKA (LBF)

Satellite

Cloud Top Pressure	Effective Cloud Amount < 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	35	10	0	0
400 - 700	0	0	0	0
PCT > 700	0	0	0	25
PCT = 1000	25	0	0	0

Ground

Station Reports no significant weather
Scattered Clouds at 3000 feet
Scattered Clouds at 10000 feet

TABLE 2

INTERCOMPARISON OF SATELLITE AND GROUND OBSERVATIONS
OF CLOUD COVER FOR 1400 UT 27 JULY 1989
AT CLEVELAND, OHIO (CLE)

Satellite

	Effective Cloud Amount			
Cloud Top Pressure	< 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	0	0	0	100
400 - 700	0	0	0	0
PCT > 700	0	0	0	0
PCT = 1000	0	0	0	0

Ground

Station Reports thundershowers, fog, and haze
Overcast at 1300 feet

TABLE 3

INTERCOMPARISON OF SATELLITE AND GROUND OBSERVATIONS
OF CLOUD COVER FOR 0600 UT 29 JULY 1989
AT PHOENIX, ARIZONA (PHX)

Satellite

	Effective Cloud Amount			
Cloud Top Pressure	< 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	40	40	0	0
400 - 700	0	0	0	20
PCT > 700	0	0	0	0
PCT = 1000	0	0	0	0

Ground

Station Reports clear sky

TABLE 4

INTERCOMPARISON OF SATELLITE AND GROUND OBSERVATIONS
OF CLOUD COVER FOR 1700 UT 13 SEPTEMBER 1989

AT GRAND ISLAND, NEBRASKA (GRI)

Satellite

Cloud Top Pressure	Effective Cloud Amount < 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	35	0	0	0
400 - 700	0	5	0	0
PCT > 700	0	0	0	60
PCT = 1000	0	0	0	0

Ground

Station Reports no significant weather
Overcast at 2900 feet

AT DES MOINES, IOWA (DSM)

Satellite

Cloud Top Pressure	Effective Cloud Amount < 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	20	60	0	0
400 - 700	0	10	10	0
PCT > 700	0	0	0	0
PCT = 1000	0	0	0	0

Ground

Station Reports no significant weather
Scattered Clouds at 2000 feet
Overcast at 25000 feet

AT KANSAS CITY, MISSOURI (MCI)

Satellite

Cloud Top Pressure	Effective Cloud Amount < 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	0	0	30	70
400 - 700	0	0	0	0
PCT > 700	0	0	0	0
PCT = 1000	0	0	0	0

Ground

Station Reports rain showers
Scattered Clouds at 800 feet
Overcast at 2700 feet

TABLE 5

INTERCOMPARISON OF SATELLITE AND GROUND OBSERVATIONS
OF CLOUD COVER

VAS RESULTS FOR GROUND REPORTS OF TOTALLY CLEAR SKY
(Number of Observations = 529)

Cloud Top Pressure	Effective Cloud Amount < 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	1	1	1	1
400 - 700	0	0	0	2
PCT > 700	0	0	0	17
PCT = 1000	77	0	0	0

TABLE 6

INTERCOMPARISON OF SATELLITE AND GROUND OBSERVATIONS
OF CLOUD COVER

(6a) VAS RESULTS FOR GROUND REPORTS OF OVERCAST
AT LESS THAN 10000 FEET
(Number of Observations = 218)

Cloud Top Pressure	Effective Cloud Amount < 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	7	11	24	14
400 - 700	0	3	5	14
PCT > 700	0	0	0	17
PCT = 1000	5	0	0	0

(6b) VAS RESULTS FOR GROUND REPORTS OF OVERCAST LAYER
BETWEEN 10000 - 25000 FEET
(Number of Observations = 6)

Cloud Top Pressure	Effective Cloud Amount < 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	12	5	48	3
400 - 700	0	0	5	13
PCT > 700	0	0	0	12
PCT = 1000	3	0	0	0

(6c) VAS RESULTS FOR GROUND REPORTS OF OVERCAST
AT GREATER THAN 25000 FEET
(Number of Observations = 16)

Cloud Top Pressure	Effective Cloud Amount < 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	16	31	31	4
400 - 700	1	0	2	6
PCT > 700	0	0	0	10
PCT = 1000	0	0	0	0

TABLE 7

INTERCOMPARISON OF SATELLITE AND GROUND OBSERVATIONS
OF CLOUD COVER

(7a) VAS RESULTS FOR GROUND REPORTS OF SCATTERED DECKS
BETWEEN 10000 - 25000 FEET
(Number of Observations = 90)

	Effective Cloud Amount			
Cloud Top Pressure	< 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	9	4	2	1
400 - 700	1	2	2	5
PCT > 700	0	0	0	27
PCT = 1000	48	0	0	0

(7b) VAS RESULTS FOR GROUND REPORTS OF BROKEN DECKS
BETWEEN 10000 - 25000 FEET
(Number of Observations = 37)

	Effective Cloud Amount			
Cloud Top Pressure	< 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	14	17	12	2
400 - 700	2	4	5	10
PCT > 700	0	0	0	18
PCT = 1000	17	0	0	0

(7c) VAS RESULTS FOR GROUND REPORTS OF SCATTERED DECKS
AT HIGHER THAN 25000 FEET
(Number of Observations = 135)

	Effective Cloud Amount			
Cloud Top Pressure	< 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	5	3	1	0
400 - 700	1	0	0	1
PCT > 700	0	0	0	22
PCT = 1000	65	0	0	0

(7d) VAS RESULTS FOR GROUND REPORTS OF BROKEN DECKS
AT HIGHER THAN 25000 FEET
(Number of Observations = 56)

	Effective Cloud Amount			
Cloud Top Pressure	< 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	19	18	8	0
400 - 700	1	1	0	5
PCT > 700	0	0	0	23
PCT = 1000	25	0	0	0

TABLE 8

INTERCOMPARISON OF SATELLITE AND GROUND OBSERVATIONS OF CLOUD COVER

(8a) VAS RESULTS FOR GROUND REPORTS OF MIXED CLOUD LAYERS AT LOW/MID LEVELS
(Number of Observations = 310)

	Effective Cloud Amount			
Cloud Top Pressure	< 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	12	13	13	6
400 - 700	1	2	3	7
PCT > 700	0	0	0	22
PCT = 1000	20	0	0	0

(8b) VAS RESULTS FOR GROUND REPORTS OF MIXED CLOUD LAYERS AT LOW/HIGH LEVELS
(Number of Observations = 172)

	Effective Cloud Amount			
Cloud Top Pressure	< 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	13	13	13	6
400 - 700	1	1	1	5
PCT > 700	0	0	0	21
PCT = 1000	27	0	0	0

(8c) VAS RESULTS FOR GROUND REPORTS OF MIXED CLOUD LAYERS AT MID/HIGH LEVELS
(Number of Observations = 113)

	Effective Cloud Amount			
Cloud Top Pressure	< 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	12	13	12	5
400 - 700	1	2	3	5
PCT > 700	0	0	0	21
PCT = 1000	27	0	0	0

TABLE 9

INTERCOMPARISON OF SATELLITE AND GROUND OBSERVATIONS
OF CLOUD COVER

VAS RESULTS FOR GROUND REPORTS OF RAIN AND TRW REPORTS
(Number of Observations = 93)

	Effective Cloud Amount			
Cloud Top Pressure	< 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	1	12	37	32
400 - 700	0	1	7	8
PCT > 700	0	0	0	2
PCT = 1000	0	0	0	0

TABLE 10

INTERCOMPARISON OF SATELLITE AND GROUND OBSERVATIONS
OF CLOUD COVER

TEMPLATE FOR COMPARING VAS RESULTS AND GROUND REPORTS

	Effective Cloud Amount			
Cloud Top Pressure	< 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	b1	c1	d1	e1
400 - 700	b2	c2	d2	e2
PCT > 700	x	x	x	f
PCT = 1000	a	x	x	x

Figure 1. Infrared window image of the midwestern United States on 2200 UT 22 June 1989. Locations of stations under differing cloud conditions are indicated.

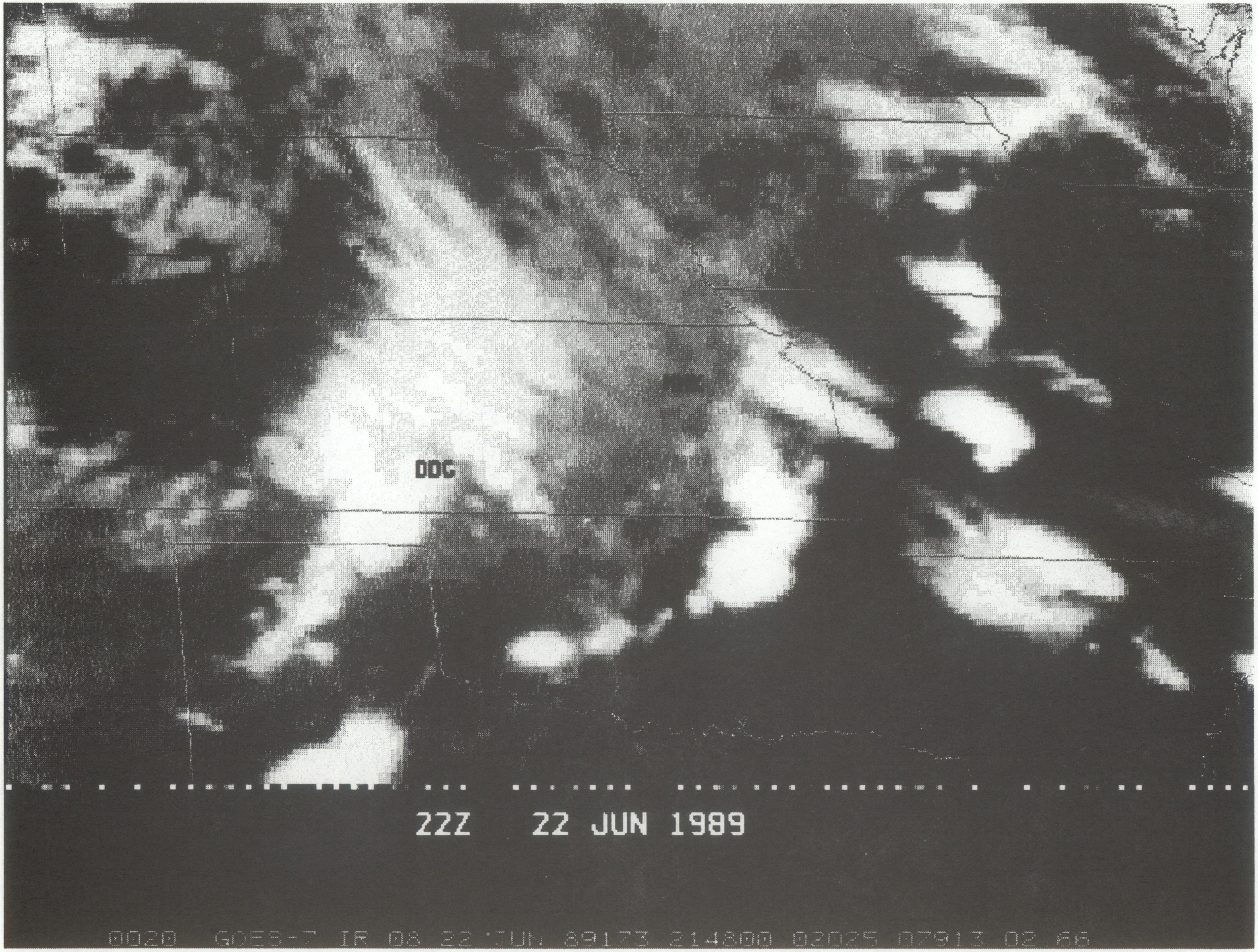


Figure 2. VAS image over the Great Lakes region on 1418 UT 27 July 1989. Bright white cumulonimbus tops are apparent from Wisconsin to western New York. At 1400 UT, a surface thundershower is reported at Cleveland, Ohio (CLE).

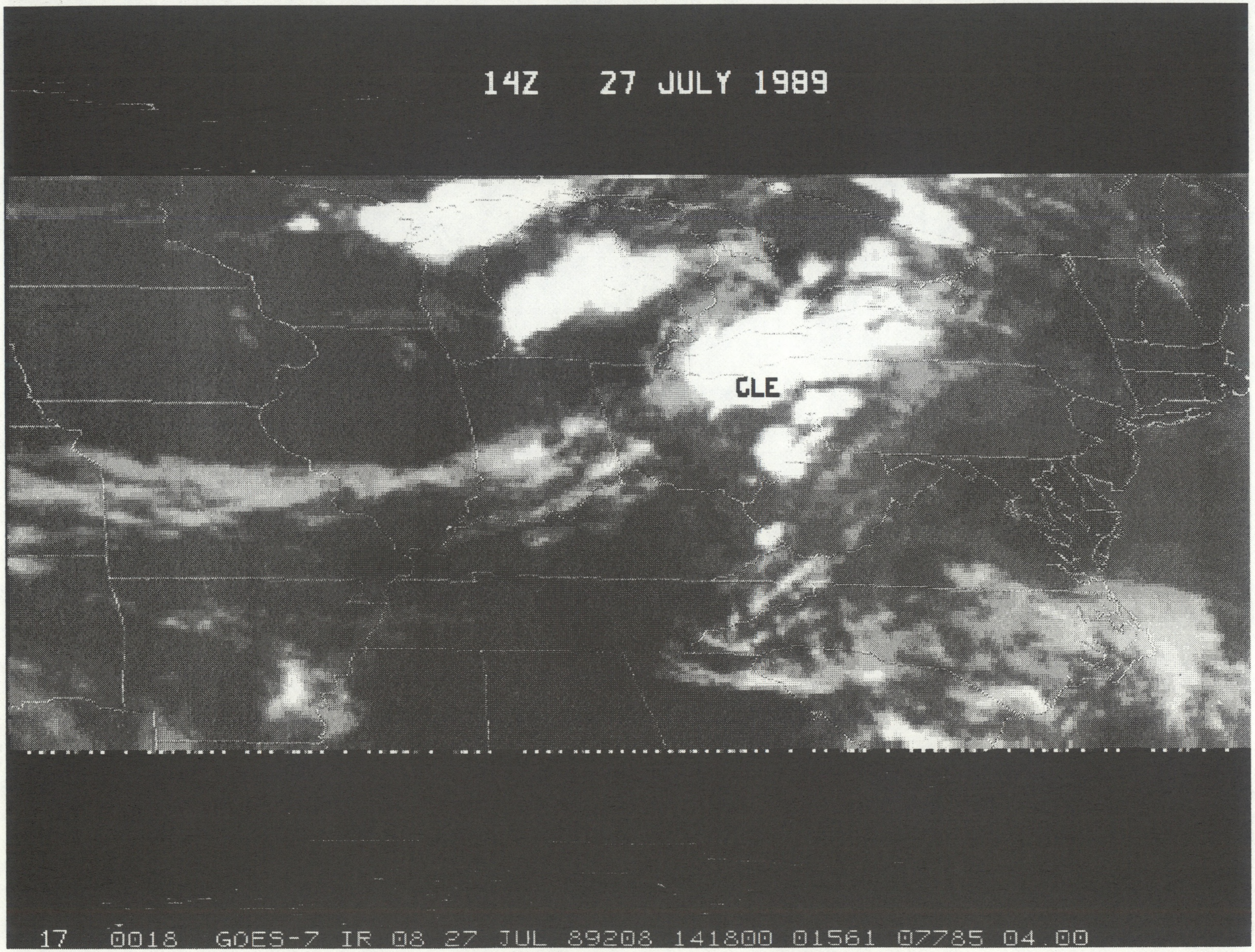
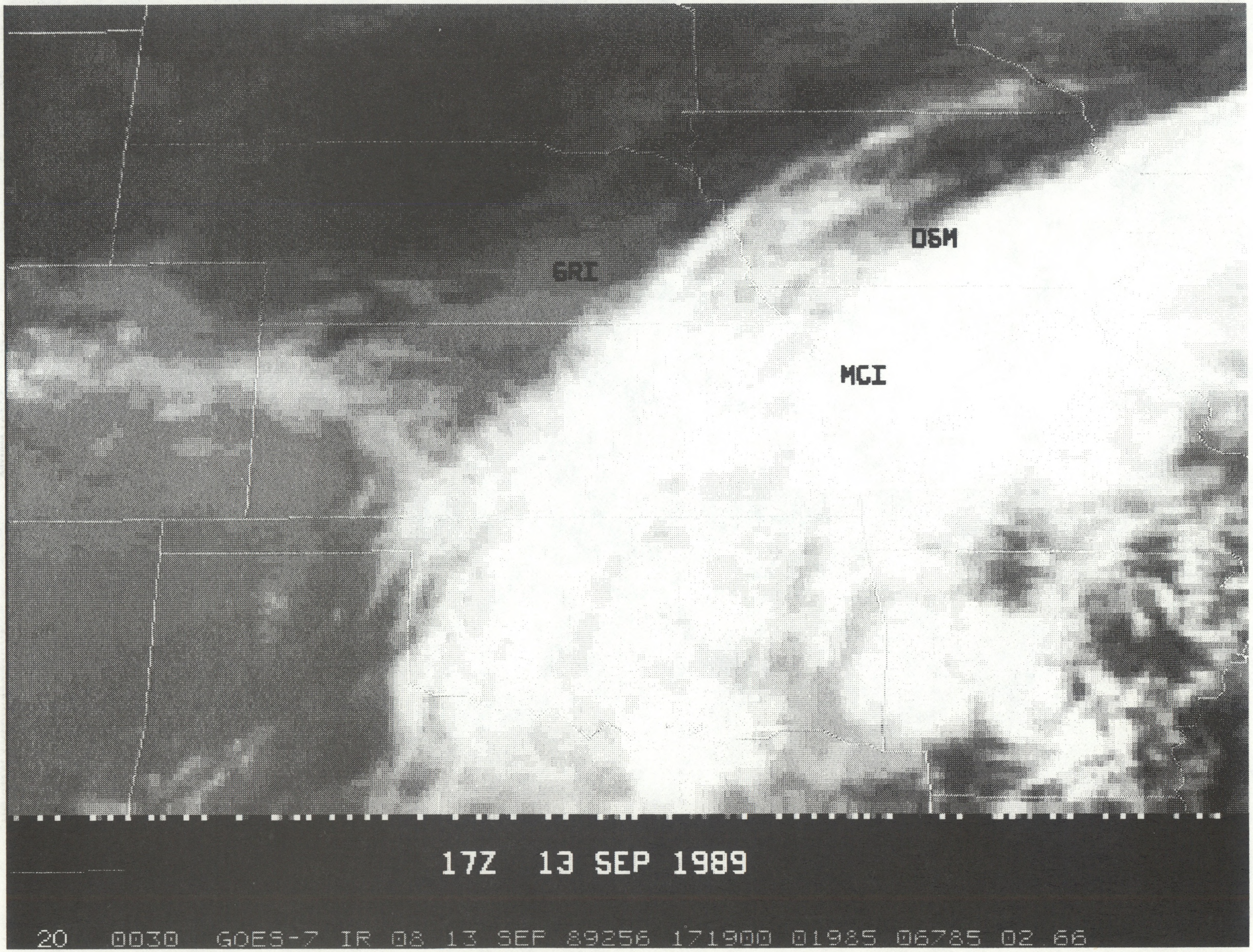


Figure 3. VAS image over the southwest United States at 0600 UT 29 July 1989. Multi-layer clouds encompass Phoenix, Arizona (PHX).

Figure 4. VAS infrared image over the midwestern United States 1700 UT 13 September 1989. Low clouds cover a broad region from Illinois, west through Kansas into Colorado, overlaid by a cirrus shield from Oklahoma to Michigan. Station locations under low cloud (GRI), the high cloud (DSM), and a low/high cloud combination (MCI) are indicated.



(Continued from inside front cover)

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