CHARACTERISTICS OF GLOBAL CLOUD COVER DERIVED FROM MULTISPECTRAL HIRS OBSERVATIONS

W. P. Menzel
NOAA/NESDIS
Madison, Wisconsin 53706

D. P. Wylie, and K. I. Strabala
Cooperative Institute for Meteorological Satellite Studies
Madison, Wisconsin 53706

1. Introduction

Clouds are actively involved in modulating the radiation budget in the earth's climate system. Variations in the amplitude and phase of the seasonal and diurnal cycles of the outgoing longwave radiation can be physically interpreted as variations in the surface temperature and cloudiness (Short and Wallace, 1980). Past estimates of the variation of the earth's outgoing longwave radiation or clouds have been derived primarily from the longwave infrared window (10-12 microns) radiances as observed from polar orbiting (Gruber and Chen, 1988) and geostationary (Minnis and Harrison, 1984a,b; Gruber, 1976) satellites.

The frequency of cirrus clouds usually has been underestimated in cloud population studies. Satellite methods of analyzing cloud cover often mistake cirrus clouds for lower level clouds or completely miss them. Most infrared window techniques do not correct for the transparency of the cirrus clouds and underestimate their altitude because their infrared brightness temperatures are warmer than the temperature associated with their true altitudes. Thin cirrus are especially hard to identify on visible satellite images because they reflect little solar radiation and appear as dark or broken cloud fields. With the multispectral infrared sensor on the NOAA HIRS and the GOES VAS satellite, reliable identification of most cirrus is now possible.

In this study, multispectral HIRS (High resolution Infrared Radiation Sounder) observations in the carbon dioxide absorption band at 15 microns have been used to calculate cloud statistics globally. The CO_2 technique calculates both cloud top pressure and emissivity from radiative transfer principles. Transmissive clouds that are partially transparent to terrestrial radiation have been reliably separated from opaque clouds in the statistics of cloud cover (Wylie and Menzel, 1989).

The CO_2 technique has been installed on the Man computer Interactive Data Access System (McIDAS) at the University of Wisconsin-Madison. 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 geostationary sounder VAS (VISSR Atmospheric Sounder) and the polar orbiting sounder HIRS (High resolution Infrared Sounder) has been published (Wylie and Menzel, 1989; Menzel et al., 1986; Susskind, 1987; Eyre and Menzel, 1989). This paper pursues the investigation of global cloud cover with the HIRS and reports on intercomparisons of the satellite cloud determinations and the ground observer cloud reports. The technique and its application to the HIRS radiances will only be briefly repeated here; more detail is available in the cited references.

2. Technique Description

The HIRS radiometer senses infrared radiation in eighteen spectral bands that lie between 3.9 and 15 microns at 25 to 40 km resolution (depending upon viewing angle) in addition to visible reflections at the same resolution. The four channels in the CO_2 absorption band at 15 microns are used to differentiate cloud altitudes and the longwave infrared window channel identifies the effective emissivity of the cloud in the HIRS field of view (FOV).

To assign a cloud top pressure to a given cloud element, the ratio of the deviations 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 FOV can be written as

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

In this equation, ϵ is the cloud emissivity, P_s the surface pressure, P_c the cloud pressure, $t(\nu,p)$ the fractional transmittance of radiation of frequency ν emitted from the atmospheric pressure level (p) arriving at the top of the atmosphere ($p = 0$), 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 satellite observed radiances in a given fov and the clear air radiances inferred from spatial analyses of satellite clear radiance observations. The right side of equation (1) is calculated from a temperature profile and the profiles of atmospheric transmittance for the spectral channels as a function of P_c, the cloud top pressure (1000 mb to 100 mb is spanned by discrete values at 50 mb intervals). In this study, global analyses of temperature and moisture fields from the National Meteorological Center (NMC) are used. The optimum cloud top pressure is determined when the absolute difference left (ν_1, ν_2) minus right (ν_1, ν_2, P_c) is a minimum.

Once a cloud height has been determined, an effective cloud amount (also referred to as effective emissivity in this paper) 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 fractional cloud cover within the FOV, $N\epsilon$ the effective cloud amount, w represents the window channel frequency, and $B[w, T(P_c)]$ is the opaque cloud radiance.

Using the ratios of radiances of the three CO_2 spectral channels, four separate cloud top pressures can be determined (14.2/14.0, 14.0/13.7, 14.0/13.4, and 13.7/13.4). Whenever $(I-I_{cl})$ is within the noise response of the instrument (roughly 1 mW/m2/ster/cm-1), the resulting P_c is rejected. Using the infrared window and the four cloud top pressures, as many as four effective cloud amount determinations can also be made. As described by Menzel (1983), the most representative cloud height and amount are those that best satisfy the radiative transfer equation for the four CO_2 channels.

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 emissivity is assumed to be unity. 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 an 8.3 micron channel correction for moisture absorption. If the moisture corrected 11.2 micron brightness temperature is within 2 degrees Kelvin of the known surface temperature (over land this is inferred from the 1000 mb NMC model analysis adjusted with observations from the Global Telecommunications System surface network; over the oceans this is the NMC sea surface temperature), then the FOV is assumed to be clear (P_c = 1000 mb) and no cloud parameters are calculated.

The CO_2 technique is independent of the fractional cloud cover; heights and effective cloud amounts can be determined for partially cloudy FOVs. However, there are several sources of error. The cloud is assumed to be of infinitesimal thickness; this introduces errors approaching one half (one quarter) the thickness of the cloud for optically thin (thick) clouds where the integrated emittance is less than (greater than) 0.6 (Smith and Platt, 1978). The HIRS CO_2 technique assumes the presence of only one cloud layer; when multiple layers are sensed it derives a cloud altitude in between the altitudes of the two separate layers. Lower clouds may be obscured. Because the HIRS FOV resolution is coarse (25 km), very small element clouds are difficult to detect. Also, because the weighting functions for the HIRS channels are broad, there is an inherent lack of vertical resolution in the measurements. Nonetheless, reliable cloud statistics can be calculated with appropriate application of the technique.

In the study of Wylie and Menzel (1989), the CO_2 cloud heights derived from VAS (VISSR Atmospheric Sounder) data were found to be of good quality when compared to three other independent sources of cloud height information. (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 appear to be good to 50 mb and the effective emissivities to .20 in most cloud types (broken clouds and stratocumulus at low levels remain elusive). Three years of VAS cloud parameter determinations reveal reasonably good agreement with the manual weather observations of Warren et al. (1986).

3. Global HIRS Cloud Statistics

A statistical summary of the HIRS cloud determinations for the week of 5-8 July 1989 (from the afternoon overpasses) is shown in Table 1. Latitudinal coverage includes 83 N to 83 S. FOVs out to 25 degrees from nadir were processed. Figure 1 shows the combined coverage of the NOAA 10 and 11 cloud determinations for one day. About 200,000 cloud parameter calculations were made for the four days. The cloud top pressure determinations were subdivided into ten vertical levels from 100 mb to 1000 mb in each row of Table 1. High clouds (those above 400 mb) comprised 26% of the observations. 28% of the observations were between 400 mb and 700 mb. Low clouds (those below 700 mb) were found 20% of the time. Clear sky conditions, labelled as 1000 mb, were found 26% of the time. The mean cloud top pressure for these four days was about 530 mb.

The effective cloud emissivities were subdivided into six intervals shown in each column of Table 1. The right column contains the opaque or near opaque cloud observations. We consider effective emissivity observations greater than 0.95 to be opaque clouds since the cloud top height derived from equation (1) is very close to the height derived from the window channel by itself. The other five columns separate the cloud height reports by effective emissivities ranging from the thin low emissivity clouds on the left to the thick high emissivity clouds on the right. Most cloud heights below 700 mb were determined from the infrared window channel and thus were assumed to have an effective emissivity of one. This precludes the interpretation of low broken cloud as cirrus.

Transmissive (also referred to as cirrus in this paper) clouds are defined as observations with effective emissivities less than 0.95. 43% of our observations fell into this category. They were found from 100 to 700 mb. Clouds opaque to infrared radiation with effective emissivities greater than 0.95 (right column) were found 31% of the time. Clear sky was found 26% of the time. Thus, 74% of the satellite observations over the globe for these four days found clouds. The mean effective cloud amount for all FOVs for these four days was 51%; this is comparable with the 43% reported by Susskind et al. for June 1979.

There was no significant variation in the cloud cover from day to day for the period of 5-8 July 1989. The single day statistics for any one of the four days did not deviate from the four day average by more than a single digit for any of the entries in Table 1.

4. HIRS Comparisons with VAS

These HIRS cloud parameter determinations have been compared to similar VAS determinations over North America for the afternoons of 17-19 July 1989. VAS has three CO_2 channels for the height determination and the FOV is roughly 10 km at mid latitudes. Table 2 shows the HIRS and the VAS statistics. Both agree on the percentage of clear FOVs (37 and 39% respectively). The HIRS sees 9% fewer FOVs filled with opaque clouds (28 versus 37%), as the larger HIRS FOV would dictate. Interestingly, the HIRS places more of the transmissive clouds at mid levels (20 versus 3%) and less at the upper levels (15 versus 21%). This may be due to to better sensitivity of the HIRS to mid levels; the VAS uses the window channel for more of its determinations and frequently places mid level transmissive clouds in the low level opaque category. The average cloud top pressure for all the HIRS determinations is 544 mb; for the VAS it is 548 mb. Overall, the agreement between the two systems is quite good.

5. Diurnal Variations Observed by NOAA 10 and 11

The afternoon (2 PM LST) and evening overpasses (10 PM LST) were compiled separately to investigate any diurnal signature in the global cloud cover. Table 3 shows the results for 17-19 July 1989. The afternoon overpass detects 27% clear, 44% transmissive, and 29% opaque FOVs. The evening overpasses shifts these numbers to 22% clear, 43% transmissive, and 35% opaque FOVs. The evening decrease in clear sky is matched by an increase in high and mid-level opaque clouds.

6. Intercomparison with Ground Observations

A demonstration of the utility of VAS CO_2 cloud parameters (cover, height, emissivity) in supplementing conventional ground observations is currently underway. The geostationary observations are readily synchronized with the ground reports. Three weeks of comparisons in summer 1989 of the satellite derived cloud information with surface observations are revealing that the satellite can supplement surface measurements of cloud cover above 10000 feet. Preliminary conclusions are that (a) above 400 mb (25000 ft) the satellite information is more reliable, (b) between 400 and 700 mb (10000 ft) the satellite and ground observations are complementary, (c) below 700 mb the surface observation is preferable.

More specifically, several examples are showing that the satellite can succesfully distinguish cloud versus no cloud, the satellite can see multilayers above those observed from ground, and often the satellite provides important missing data when the ground observers view is obstructed (by night, fog, low cloud cover, blowing dust, ...).

Figure 2 shows an example where both 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 4000 feet, and overcast skies at 7000 feet. The satellite reports 30% cirrus higher than 400 mb with 25% cirrus and 45% opaque cloud between 400 and 700 mb. Both observations seem correct. 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 seem correct. 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. Under scattered (less than 50% cover) clouds, North Platt, Nebraska (LBF) reports scattered cloud at 3000 feet and also at 10000 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. Table 4 details the ground and satellite observations.

The comparison between satellite and ground is performed in the following way. Satellite determinations of height and emissivity for twenty fields of view (FOV) of roughly 10 km resolution centered over to site of the ground observation are statistically segmented. Emissivities are sectioned off at .33, .66, .95, and 1.0 and heights are sectioned off at surface, 700 mb, 400 mb and above. The histograms of satellite observations are investigated for patterns that can reveal the ground observation.

The average satellite response was tabulated for given ground characterizations of the cloud cover and weather for three weeks in July 1989. The averaged satellite derived parameters exhibit features which can be used to distinguish scattered to broken conditions in mid to high clouds, overcast clouds at all levels, and presence of rain and thundershowers. Less pronounced signatures occur with multilayer clouds. The results of these intercomparisons are briefly summarized on the following paragraphs.

Histograms of satellite derived cloud parameters concurrent with ground observed single layer overcast indicate dominance in 400 mb and above sensed clouds. 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 clouds bases. By providing information on clouds aloft, the satellite supplements the ground observations with upper level cloud information roughly 80% of the time when low or mid level overcast conditions are reported.

The CO_2 technique also demonstrates the capability to distinguish scattered (less than 50%) from broken (greater than 50%) clouds above 700 mb. Satellite determinations of clear skies decrease by more than half (50% to 20%) when the ground observations go from scattered to broken, in both mid and high observed clouds. A good differentiation between scattered and broken clouds seems to occur in the satellite effective emissivity between .66 - .95; when more than 10% of the satellite observations fall in this category, the ground observer usually reports broken cloud cover.

Satellite results for ground observed multilayer clouds can be distinguished from ground observed scattered decks through the number of clear sky reports; multilayer indicates fewer clear FOVs than single layer scattered (20% versus 50%). However, it is difficult to distinguish satellite results for ground observed multilayer clouds versus ground observed broken decks. The averaged parameters are very similar for all three sets of multilayer clouds, with the statistics dominated by clouds sensed above 400 mb.

Of particular interest is the capability of the satellite to detect upper level transmissive clouds (scattered or broken), either by themselves or superimposed on lower clouds. Tables 5a and 5b show the satellite results for all ground reports where either situation was observed (about 300 comparisons in all). Without the lower clouds roughly 40% of the FOVs are clear, 20% show lower clouds, 35% report upper level transmissive clouds, and 5% report upper level opaque clouds. The 20% lower clouds are probably the window channel mistakes. With a lower cloud deck present, only about 10% of the FOVs are clear, 15% show lower clouds, 60% report upper level transmissive clouds, and 15% report upper level opaque clouds. While there is an indication of lower clouds, most of the observations focus on the upper level transmissive clouds. The satellite definitely is detecting upper level cirrus.

Table 5c summarizes the satellite results in situations where the ground observer reported precipitation with thundershowers. In every case (46 in all) the satellite observed broken to overcast conditions and more than 80% of the clouds were above 400 mb and only 2% below 700 mb. The cold cumulonimbus cloud tops associated with thundershowers were readily sensed by the CO_2 technique. Opaque observations in more than 40% of the FOVs can serve as an indicator of surface thundershowers.

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. Errors may exist in satellite sensed low opaque clouds due to the underestimation of thin transmissive clouds and the window channel evaluation of ground as low cloud. These inaccuracies along with the ground based bottom-to-top view, make ground observations preferable below 700 mb. Alternatively, the satellites unobstructed view of high clouds, and accurate cloud top measurement (within 50 mb), make it a more reliable technique above 400 mb.

7. Conclusions

The CO_2 method for calculating cloud parameters (height and amount) has produced good results with HIRS radiances. Global cloud characteristics for 5-8 July 1989 show 26% clear, 43% transmissive, and 31% opaque FOVs. Thin transmissive clouds are reliably classified in more than 80% of the FOVs where thin clouds are suspected to occur based on ground observations. Intercomparisons with the VAS cloud parameters over North America for 17-19 July 1989 are very good; the HIRS shows more skill in assigning transmissive clouds to mid-levels but the average heights agree within in accuracy of the technique. Intercomparisons of NOAA 10 and 11 indicate a modest increase in opaque clouds (5%) between the afternoon and evening overpasses. The satellite and ground observer reports of cloudiness complement each other; the satellite does better at high levels with its top down view while the ground observer is more reliable at low levels with his bottom up view.

The high frequency of transmissive or cirrus cloud cover (43%) the globe for 5-8 July 1989 corroborates earlier VAS studies over North America; it points to the extreme importance of reliable cirrus detection schemas in any global cloud climatology studies.

8. References

Chahine, M. T., 1974: Remote sounding of cloudy atmospheres. I. The single cloud layer. J. Atmos. Sci., 31, 233-243.

Eyre, J. R., and W. P. Menzel, 1989: Retrieval of cloud parameters from satellite sounder data: A simulation study. J. Appl. Meteor., 28, 267-275.

Gruber, A. and T. S. Chen, 1988: Diurnal variation of outgoing longwave radiation. J. Clim., 8, 1-16.

Gruber, A., 1976: An estimate of the daily variation of cloudiness over the GATE A/B area. Mon. Wea. Rev., 104, 1036-1039.

Menzel, W. P., W. L. Smith, and T. R. Stewart, 1983: Improved cloud motion wind vector and altitude assignment using VAS. J. Clim. Appl. Meteor., 22, 377-384.

Menzel, W. P., D. P. Wylie, and A. H. Huang, 1986: Cloud top pressures and amounts using HIRS CO_2 channel radiances. Technical Proceedings of the Third International TOVS Study Conference, Madison, Wisconsin, 173-185.

Minnis, P. and E. F. Harrison, 1984a: Diurnal variability of regional cloud and clear sky radiative parameters derived from GOES data. Part I. J. Clim. Appl. Meteor., 23, 993-1011.

Minnis, P. and E. F. Harrison, 1984b: Diurnal variability of regional cloud and clear sky radiative parameters derived from GOES data. Part II. November 1978 cloud distributions. J. Clim. Appl. Meteor., 23, 1012-1031.

Short, D. A. and J. M. Wallace, 1980: Satellite inferred morning to evening cloudiness changes. Mon. Wea. Rev., 108, 1160-1169.

Smith, W. L., H. M. Woolf, P. G. Abel, C. M. Hayden, M. Chalfant, and N. Grody, 1974: Nimbus 5 sounder data processing system Part I: Measurement characteristics and data reduction procedures. NOAA Tech. Memo. NESS 57, 99pp.

Smith, W. L. and C. M. R. Platt, 1978: Intercomparison of radiosonde, ground based laser, and satellite deduced cloud heights. J. Appl. Meteor., 17, 1796-1802.

Susskind, J., D. Reuter, and M. T. Chahine, 1987: Cloud fields retrieved from analysis of HIRS/MSU sounding data. J. Geophys. Res., 92, 4035-4050.

Warren, S. G., C. J. Hahn, J. London, R. M. Chervin, and R. L. Jenne, 1986: Global distribution of total cloud cover and cloud type amounts over land. NCAR Tech. Note NCAR/TN-273+STR, 228pp.

Wylie, D. P. and W. P. Menzel, 1989: Two years of cloud cover statistics using VAS. J. Clim., Vol. 2, No. 4, 380-392.

TABLE 1

CLOUD STATISTICS FOR THE GLOBE 5-8 JULY 1989

	Effective Emissivity					
	.00-.19	.20-.39	.40-.59	.60-.79	.80-.94	.95-1.
Level (mb)						
100-199	2%	1%	0%	1%	1%	1%
200-299	2	1	1	1	1	1
300-399	3	2	2	2	2	2
400-499	2	2	2	2	2	2
500-599	0	2	2	2	0	2
600-699	0	1	2	2	0	3
700-799	0	0	0	0	0	6
800-899	0	0	0	0	0	8
900-999	0	0	0	0	0	6
1000 (clear)	26	0	0	0	0	0
	35%	9%	9%	10%	6%	31%

TABLE 2

INTERCOMPARISON OF HIRS AND VAS DETERMINATIONS OF CLOUD CHARACTERISTICS OVER NORTH AMERICA FOR 17 -19 JULY 1989

VAS

	Effective Emissivity			
Cloud Top Pressure	< 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	5	6	10	6
400 - 700	1	1	1	2
PCT > 700	0	0	0	29
PCT = 1000	39	0	0	0

HIRS

	Effective Emissivity			
Cloud Top Pressure	< 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	4	6	5	7
400 - 700	6	8	6	2
PCT > 700	0	0	0	19
PCT = 1000	37	0	0	0

TABLE 3

INTERCOMPARISON OF HIRS AFTERNOON AND EVENING DETERMINATIONS OF CLOUD CHARACTERISTICS OVER THE GLOBE FOR 17 -19 JULY 1989

AFTERNOON (2 PM)

	Effective Emissivity			
Cloud Top Pressure	< 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	8	6	6	3
400 - 700	6	10	8	5
PCT > 700	0	0	0	21
PCT = 1000	27	0	0	0

EVENING (10 PM)

	Effective Emissivity			
Cloud Top Pressure	< 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	8	6	6	5
400 - 700	6	9	8	9
PCT > 700	0	0	0	21
PCT = 1000	22	0	0	0

TABLE 4

INTERCOMPARISON OF SATELLITE AND GROUND OBSERVATIONS OF CLOUD COVER FOR 2200 UT 12 JULY 1989

(4a) AT MANHATTEN, KANSAS (MHK)

Satellite

	Effective Emissivity			
Cloud Top Pressure	< 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 ft
Broken Clouds at 4000 ft
Overcast at 7000 ft

(4b) AT DODGE CITY, KANSAS (DDC)

Satellite

	Effective Emissivity			
Cloud Top Pressure	< 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 ft
Overcast at 5500 ft

(4c) AT NORTH PLATT, NEBRASKA (LBF)

Satellite

	Effective Emissivity			
Cloud Top Pressure	< 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 ft
Scattered Clouds at 10000 ft

TABLE 5

INTERCOMPARISON OF SATELLITE AND GROUND OBSERVATIONS OF CLOUD COVER

(5a) VAS RESULTS FOR GROUND REPORTS OF SCATTERED OR BROKEN CLOUDS AT GREATER THAN 15000 FT WITHOUT LOWER CLOUDS

(Number of Observations = 94)

	Effective Emissivity			
Cloud Top Pressure	< 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	14	12	9	1
400 - 700	1	1	1	3
PCT > 700	0	0	0	20
PCT = 1000	38	0	0	0

(5b) VAS RESULTS FOR GROUND REPORTS OF SCATTERED OR BROKEN CLOUDS AT GREATER THAN 15000 FT WITH LOWER CLOUDS

(Number of Observations = 182)

	Effective Emissivity			
Cloud Top Pressure	< 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	12	16	23	8
400 - 700	1	2	5	7
PCT > 700	0	0	0	15
PCT = 1000	11	0	0	0

(5c) VAS RESULTS FOR GROUND REPORTS OF RAIN and TRW REPORTS

(Number of Observations = 46)

	Effective Emissivity			
Cloud Top Pressure	< 0.33	< 0.66	< 0.95	> 0.95
PCT < 400	1	11	37	33
400 - 700	0	1	8	7
PCT > 700	0	0	0	2
PCT = 1000	0	0	0	0

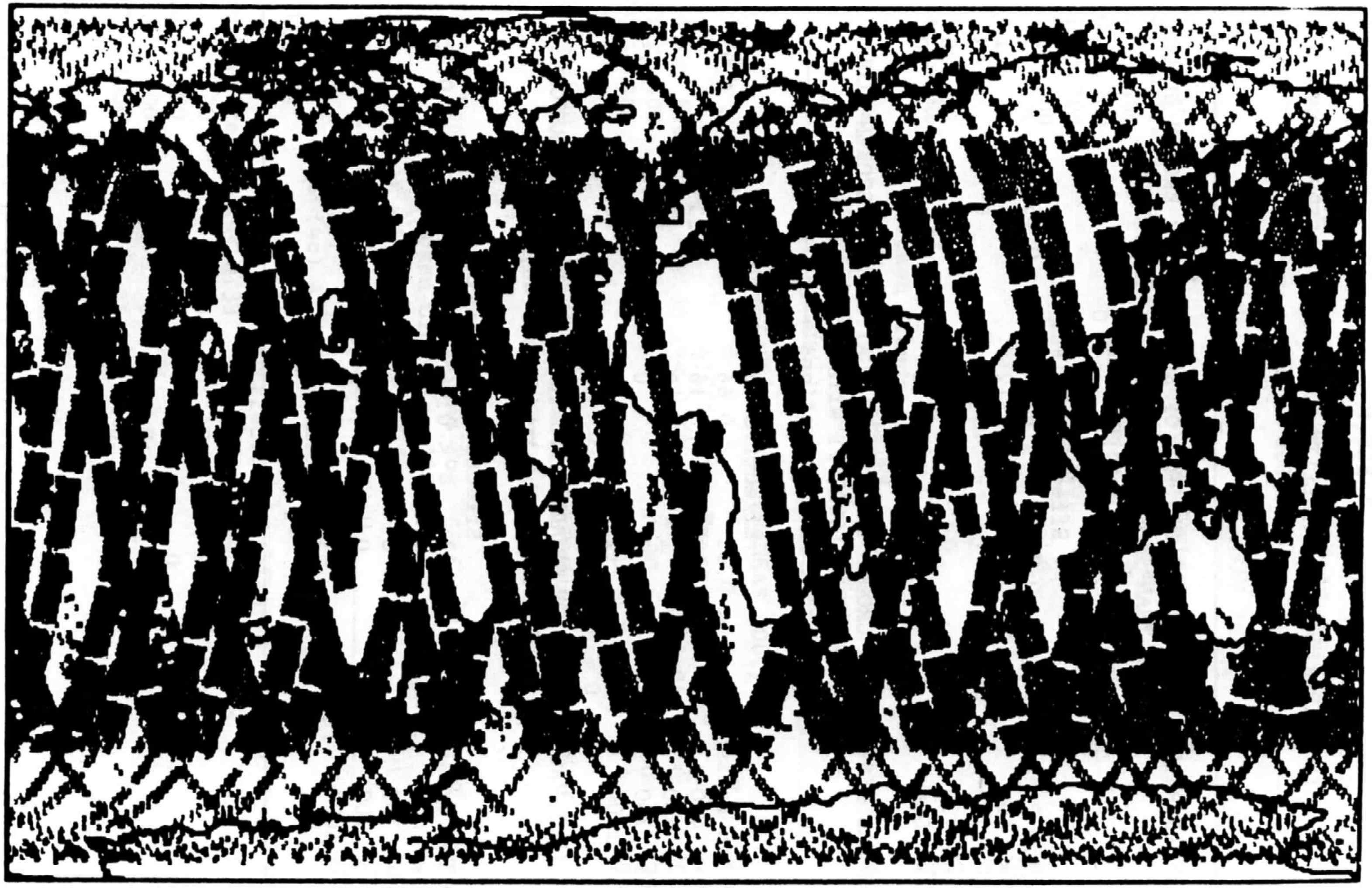

Figure 1. An example of the combined coverage achieved with NOAA 10 and 11 for a given day. Cloud determinations were made for fields of view out to 25 degrees from nadir.

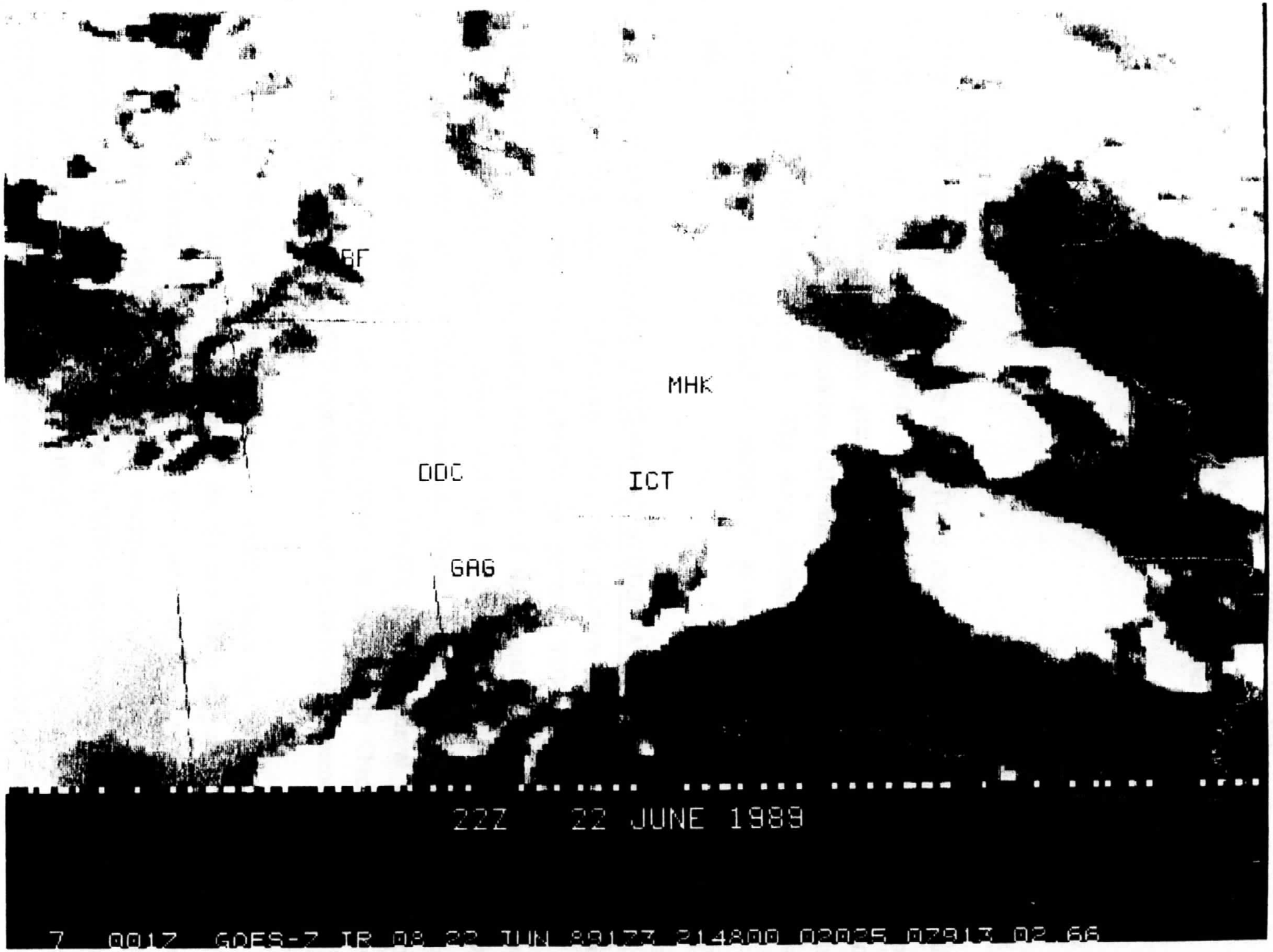

Figure 2. Infrared window image of the midwestern United States on 22 UT 22 June 1989. Locations of stations under differing cloud conditions are indicated

THE TECHNICAL PROCEEDINGS OF THE FIFTH INTERNATIONAL TOVS STUDY CONFERENCE

Toulouse, France

July 24-28, 1989

Edited by A. CHEDIN

Laboratoire de Météorologie Dynamique (CNRS)
Ecole Polytechnique,
91128 Palaiseau Cedex
France

January 1990