PICTURE OF THE MONTH

Fog and Stratus "Invisible" in Meteorological Satellite Infrared (IR) Imagery

JOHN A. ERNST

National Environmental Satellite Service, NOAA, Satellite Field Services Station, Washington, D.C. 20233

(16 June 1975 and 1 August 1975)

The non-appearance in meteorological satellite imagery of certain cloud features is neither an unusual nor an unreported occurrence. Rao (1975) described cirrus clouds that were "invisible" to the 0.9 km resolution NOAA-2 visible spectrum sensor. Anderson *et al.* (1969) discussed fog and stratus that could not be "seen" by satellite-borne infrared (IR) sensors.

Caused variously by spatial geometry, inherent sensor limitations, or sensed-element imposed physical constraints, this intermittent and capricious "no-show" characteristic of clouds can be disconcerting in an operational decision/benefit environment. The unwitting integration of such imparied imagery into the man-machine mix can diminish the credibility of meteorological satellite imagery. More importantly, however, this data disparity between satellite and conventional sources could mislead the unwary into forming derivative conclusions not truly representative of the real atmosphere.

This brief article discusses "invisible" fog and stratus (hereafter referred to as stratus, since satellite sensors cannot differentiate between the two) and shows, by means of an evaluation of data from the Man-Machine Interactive Processing System (MMIPS), why the IR sensor, regardless of its ground resolution capability, could not "see" the stratus in this particular instance.

In the pre-dawn hours of 2 May 1975, a slow moving cold front edged its way through the southern portions of the Gulf Coast states. Examination of the 1030 GMT equivalent IR image (an 8 km resolution IR image computer-formated into the size "equivalent" to its respective visible image size) from the Synchronous Meteorological Satellite, SMS-1 (Fig. 1a) showed scattered thin high clouds from North Carolina to northeast South Carolina with fair to clear skies from central South Carolina through Georgia to eastern Alabama. But the 1000 GMT Weather Depiction chart (transmitted on the National Facsimile System—NAFAX—at 1110 GMT told a different story (Fig. 1b).

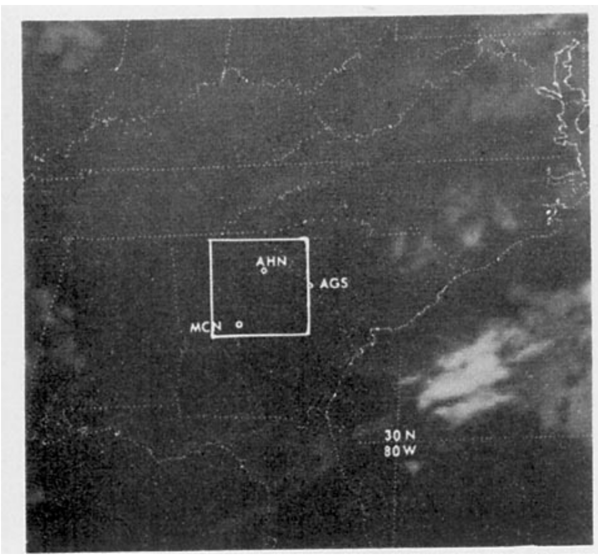

FIG. 1a. SMS-1 Equivalent IR floating sector, DB 38°N 80°W, 1030 GMT 2 May 1975, showing an apparent relatively cloud-free area in central and northern Georgia.

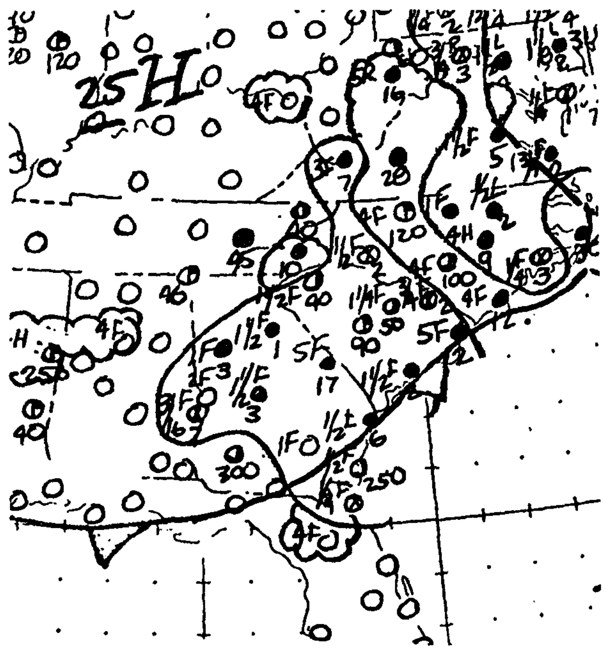

FIG. 1b. Weather Depiction Chart, 1000 GMT 2 May 1975, showing fog and stratus throughout most of Georgia and South Carolina.

At variance with the SMS-1 IR image, the Weather Depiction Chart showed an extensive area of fog and stratus covering much of Georgia and South Carolina. Which data source then, space-view or surface-view, most faithfully mirrored the state of the atmosphere? It would seem from the number of station reports and the size of the area involved that ground observation was more truthful than satellite observation in this instance. Because of the largeness of the area of concern, the ground resolution capability (areal discrimination) of 8 km does not offer a sufficient explanation for the discrepancy. At 1130 GMT, 47 minutes past sunrise at Athens, Ga. (AHN), the morning's first effective visible image over eastern North America was taken (Fig. 2). This visible image *did* show the stratus, and thus provided a clue to understanding the earlier apparent data disparity.

It is a characteristic of meteorological satellite IR sensors that the radiance detected is the total of cloud radiance, radiance partially transmitted from below the cloud, and from above the cloud. If the total radiance for a particular spot in the viewing scene is nearly the same as that for the surrounding environment, then the sensor cannot distinguish (within the instrument's sensitivity limit) cloud from background (be it land, ocean, or lower clouds). If there is little or no temperature difference between the cloud and its environment, then the cloud is effectively "invisible" in IR imagery.

One indication that this was indeed the case for this particular day was obtained by an inspection and evaluation of radiance temperature data displayed on the MMIPS.

The MMIPS ingests, stores, and operates on raw radiance count data from the SMS. By means of a calibration curve empirically determined for the SMS-1

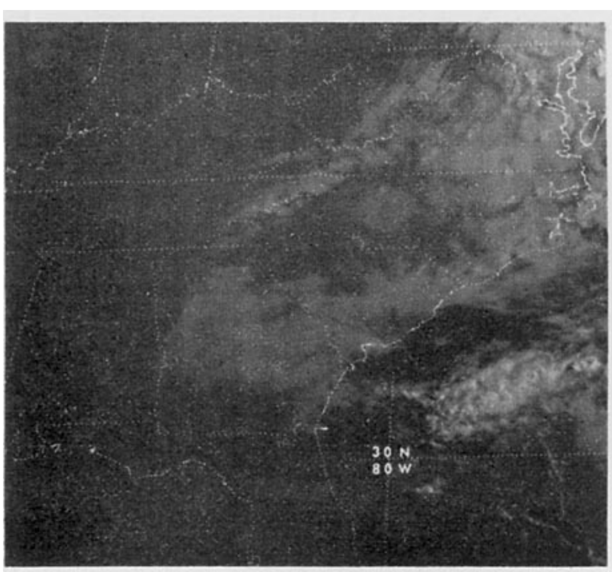

Fig. 2. SMS-1 Visible floating sector, DB 38°N 80°W, 1130 GMT 2 May 1975, showing the extensive fog and stratus (compare with IR picture in Fig. 1a).

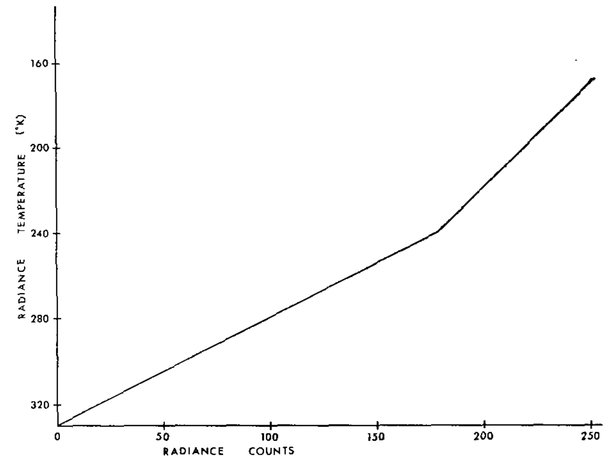

Fig. 3. Graph showing empirically determined VISSR calibration curve for IR channel correlating radiance "counts" (abscissa) to radiance temperature (ordinate) as used in the MMIPS.

Visible and Infrared Spin-Scan Radiometer (VISSR) (Fig. 3), the radiance counts are converted to radiance temperatures and displayed via various output devices for the operator's inspection. (For a detailed discussion of the various data flow paths and the intricacies of the visible/IR channel calibration procedures, see Bristor, 1975.) The data field can then be entered into and manipulated by the operator. A square box of 222 km on a side, centered at approximately 33.5°N, 82.5°W (box on Fig. 1), was electronically superimposed over data previously sectorized for the area of interest (Alabama, Georgia, and South Carolina). The radiance temperature field within the box was extracted and displayed on a cathode ray tube (CRT) for examination.

Values shown on the CRT ranged from 286 K (13°C) to 288 K (15°C) with a mode of 288 K. The range spread of 2°C over relatively flat terrain appears consistent with the findings of earlier investigators regarding the uniformity of stratus/fog cloud-top temperature (Gurka, 1974). The box, however, was purposely positioned with the aid of the visible image, so that a cloud-free area as well as cloud were contained within. Thus, the temperature uniformity over $(222\ \text{km})^2$ would seem to offer a strong indication that both the cloud top and the surrounding land were radiating at nearly the same temperature. As an independent check on the cloud top temperature, the 1200 GMT AHN rawinsonde data were examined (Fig. 4).

At 901 mb, the temperature was recorded as 13.0°C—within the range reported by the MMIPS. Following accepted procedures (Anon., 1969), the cloud top (author's analysis shown by scalloped line on the plotted data) was placed near where the temperature and dewpoint plotted traces diverge the most. From a reasonable interpretation of the plotted data, the cloud top temperature appears to be near 13°C, or in fair agreement with the radiance temperature extracted by the MMIPS for both cloudy and clear areas. Additionally, surface

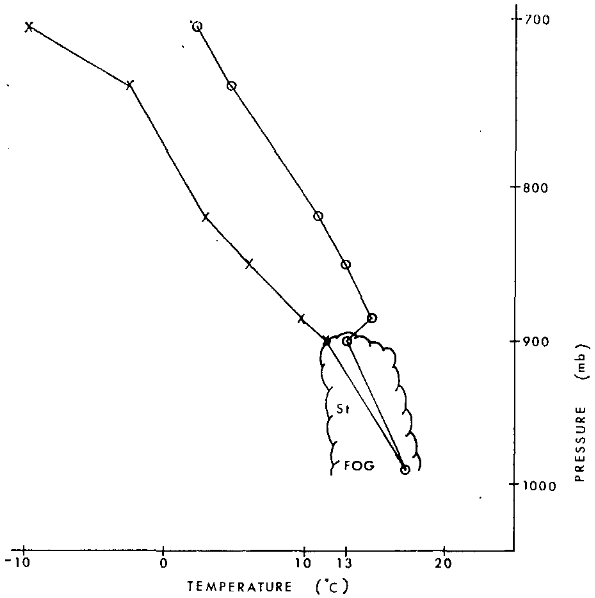

FIG. 4. Portion of plotted rawinsonde (1200 GMT 2 May 1975) for Athens, Ga. (AHN), showing a marked low-level inversion cap (901 mb) beneath which the fog and stratus had formed.

temperatures ranged from 18.8°C (66°F) at Macon, Ga. (MCN), to 17.2°C (63°F) at AHN, and showed a minimal vertical temperature difference from ground level to cloud top near the end-limit of the VISSR's detection capabilities. The VISSR's temperature difference sensitivity (discrimination) is 0.5 K and its accuracy (correspondence) is ± 3 K.

It should be noted that the MMIPS does not convert VISSR intercepted radiance values into blackbody temperatures. No correction factors for water vapor absorption in the atmospheric column above the cloud are applied. While the radiance temperature obtained is not strictly equivalent to the rawinsonde obtained environmental air temperature, the comparison of the two in an operational environment does have validity and is useful.

In summary, a minimal temperature contrast across a large area, obtained from extracted MMIPS data and confirmed by rawinsonde and surface data, provides one explanation for the non-detection of "invisible" fog and stratus in IR imagery.

REFERENCES

Anderson, R. K., *et al.*, 1969: Application of meteorological satellite data in analysis and forecasting. ESSA Technical Report NESC 51, reprinted March 1974, National Oceanic and Atmospheric Administration, Washington, D. C., 6-B-22–6-B-25.

Anon., 1969: Use of the skew T, log P diagram in analysis and forecasting. United States Air Weather Service Manual AWSM 105-124, Scott Air Force Base, Ill., 7–20.

Bristor, C. L., 1975: Central processing and analysis of geostationary satellite data. NOAA Technical Memorandum NESS 64, National Oceanic and Atmospheric Administration, Washington, D. C., 155 pp.

Gurka, J. J., 1974: Using satellite data for forecasting fog and stratus dissipation. Preprints, Fifth Conference on Weather Forecasting and Analysis, March 4–7, 1974, St. Louis, Mo., American Meteorological Society, 54 pp.

Rao, P. K., 1975: Invisible cirrus clouds in NOAA-2 VHRR imagery. Picture of the Month, *Mon. Wea., Rev.* **103**, 72–77.