NOTES

Some Examples of the Effects of Clouds and Precipitation on the Temperature Profile Retrieval for DMSP SSM/T Microwave Sounders

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ABSTRACT

Here we report a preliminary investigation of temperature retrieval utilizing the Air Force Defense Meteorological Satellite Program (DMSP) Passive Microwave Temperature Sounder (SSM/T) data under clear, cloudy and precipitating atmosphere conditions. Within the limited case studies and in the context of a statistical temperature retrieval program, we find that the recovered temperatures close to the surface suffer increased degradation as the observed rainfall rate increases when the temperature profiles are compared with radiosonde data. Differences between retrieved and observed temperatures near the surface are found to be as large as 15 K. Nonprecipitating clouds appear to have little effect on the temperature retrieval program from microwave observations.

1. Introduction

The first seven-channel microwave sounder intended for operational use was flown aboard the Air Force Defense Meteorological Satellite Program (DMSP) Block 5D satellite system launched in June 1979. The Passive Microwave Temperature Sounder (SSM/T) is a cross-track scanning radiometer in the 50–60 GHz oxygen band region. The horizontal resolution of SSM/T is a near circle of 174 km diameter in the nadir direction, while it is an ellipse with a major axis of 304 km and minor axis of ~213 km at the maximum scan angle of 36° from nadir. The main objective of SSM/T is to provide data for deriving global basis temperature profiles in the troposphere and lower stratosphere. Channel 1 (50.5 GHz) is a window channel responding strongly to the earth's surface characteristics, dense clouds and precipitation. Moreover, the peaks of weighting functions for channels 2, 3 and 4 (53.2, 54.35 and 54.9 GHz) are below about 10 km. Frequencies of other channels and the weighting functions are depicted in Fig. 1.

The prime advantage of microwave temperature sounders over infrared sounders is that the longer microwaves are much less affected by clouds and precipitation. However, since there are a number of channels whose weighting functions are below about 10 km, it would seem important to investigate the effects of clouds and precipitation on the temperature retrieval program. Here we wish to report a number of case studies for temperature retrievals using the real DMSP SSM/T data and available radiosonde temperature values under clear, cloudy and precipitating conditions. The retrieval program adopted in this investigation is a statistical method provided to us by the Air Force Global Weather Central (AFGWC) intended for operational use.

2. Temperature profile retrieval using DMSP SSM/T data

In the statistical approach for temperature retrieval, it is generally assumed that the deviation of the predicted parameter from the climatological mean may be expressed as a linear combination of the deviation of the measured data. Upon finding a linear operator which will yield a minimum mean-square deviation of the predicted temperature profile from the true temperature profile in a statistical sense, the predicted temperature profile may be obtained. The linear operator, called the predictor matrix, may be expressed in terms of a covariance matrix, which can be constructed experimentally by collecting coincidences of radiances derived from remote sounders with temperature values obtained from direct soundings. Because the surface emissivity has a profound influence on the brightness temperatures for channels whose weighting functions peak low in the atmosphere, its effect is first removed in the statistical retrieval package utilizing the surface channel. The method

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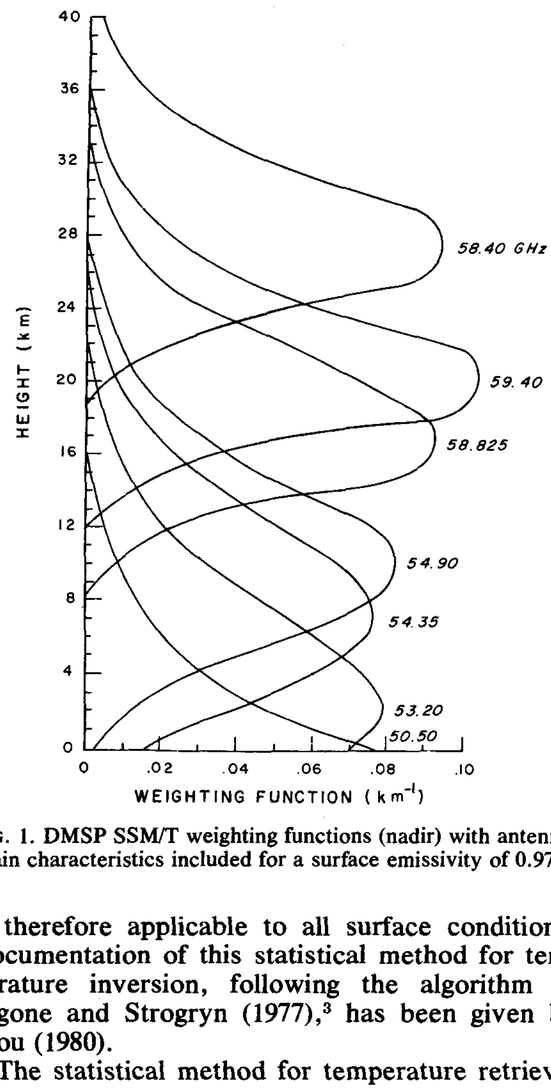

FIG. 1. DMSP SSM/T weighting functions (nadir) with antenna gain characteristics included for a surface emissivity of 0.97.

is therefore applicable to all surface conditions. Documentation of this statistical method for temperature inversion, following the algorithm of Rigone and Strogryn (1977),[3] has been given by Liou (1980).

The statistical method for temperature retrieval was applied to a number of cases where SSM/T and radiosonde data were both available. Two days, 30 October 1979 and 23 November 1979, were chosen during which significant cloud and precipitation events were present over the continental United States. The cases selected are presented in Table 1 where the satellite pass times are the actual observation times of the SSM/T instrument. We find that the scan times are generally between 0000 and 0600 LT on these two days. Thus, the 0000 LT radiosonde observations were deemed most representative and were used in the comparisons.

Fig. 2 shows the retrieval temperature profiles for the four clear cases; two on 30 October 1979 and two on 23 November 1979. The retrieved temperature profiles compare reasonably well with nearby radiosonde data in view of the statistical method used. Generally, we found that the statistical method is working properly when the actual profile is smooth and when no inversion is present.

The retrieved temperature profiles under cloud conditions are illustrated in Fig. 3. Apparently, the temperature profile retrieval program using microwave frequencies in the 60 GHz oxygen band is affected insignificantly by non-precipitating clouds. Compared with temperatures obtained from radiosondes, the retrieved patterns involving clouds are similar to those under clear conditions. Note that in each diagram the percentage of cloud cover is depicted. The fraction of cloud cover was estimated from the field of view of the SSM/T radiometer along the satellite subtrack mapped on the colocated DMSP infrared picture. Generally, the retrieved and observed (radiosonde) temperatures in clear and cloudy conditions are within ~5 K.

In the final figure (Fig. 4) we show the retrieved temperature profiles under precipitating conditions. Again, four cases are presented. Two cases are selected from 30 October 1979; both have a 5 mm h^{-1} rainfall rate with 30% cloud cover in the field of view of the SSM/T. In the other two cases, selected from 23 November 1979, both indicate a 1 mm h^{-1} rainfall rate but with cloud covers varying from 50 to 80%. The most distinct feature in the retrieved temperature profiles using the statistical covariance method for precipitating cases is the sig-

[3] Rigone, J. L., and A. P. Strogryn, 1977: Data processing for the DMSP Microwave Radiometer System. *Proc. 11th Int. Symp. Remote Sensing of the Environment.* University of Michigan, 1599–1608.

TABLE 1. Selected cases for temperature retrieval exercises.

Station	Satellite pass time	Latitude (°N)	Longitude (°W)	Case type
Centerville, AL	0346 LT 30 Oct 79	32.54	87.15	Clear
Little Rock, AR	0346 LT 30 Oct 79	34.44	92.14	Clear
Dodge City, KS	0432 LT 23 Nov 79	37.46	99.58	Clear
Glasgow, MT	0435 LT 23 Nov 79	48.13	106.37	Clear
Bismark, ND	0350 LT 30 Oct 79	46.46	100.45	Cloudy
Medford, OR	0531 LT 30 Oct 79	42.22	122.52	Cloudy
Green Bay, WI	0253 LT 23 Nov 79	44.29	88.08	Cloudy
Monterrey, Mexico	0429 LT 23 Nov 79	25.52	100.12	Cloudy
Dodge City, KS	0348 LT 30 Oct 79	37.46	99.58	Precipitating
Omaha, NE	0349 LT 30 Oct 79	41.22	96.01	Precipitating
Pittsburgh, PA	0252 LT 23 Nov 79	40.32	80.14	Precipitating
Spokane, WA	0435 LT 23 Nov 79	47.38	117.32	Precipitating

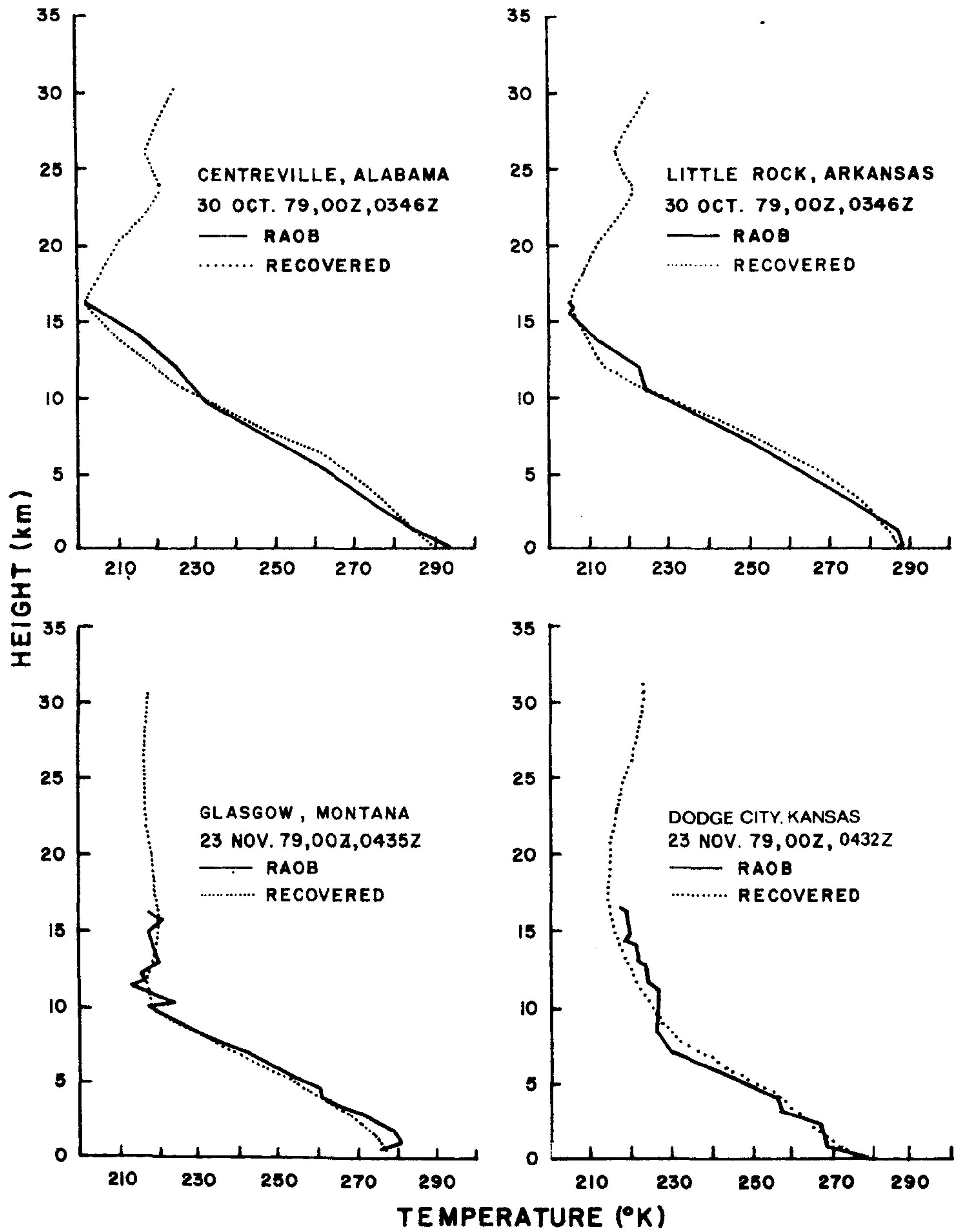

FIG. 2. Comparisons of the retrieved temperature profiles (dots) with radiosonde data (solid lines) for four clear cases.

nificant and consistent deviation from the radiosonde data in the lower boundary layer where precipitation takes place. In the moderate 5 mm h^{-1} rainfall rate cases, the differences between the retrieved and radiosonde temperature profiles near the surface are as large as 10–15 K. It should be noted that precipitation in these two cases covers only ~30% within the field of view of SSM/T. For the cases involving the 1 mm h^{-1} rainfall rate, about 5–10 K differences near the ground are observed.

3. Conclusion

An investigation of the effects of precipitation on temperature profile retrieval using DMSP SSM/T microwave data has been carried out. The retrieval method adopted in this study is the statistical method developed at the Air Force Global Weather Central in which the effect of surface temperature and emissivity is removed in the retrieval program. For a number of case studies in which

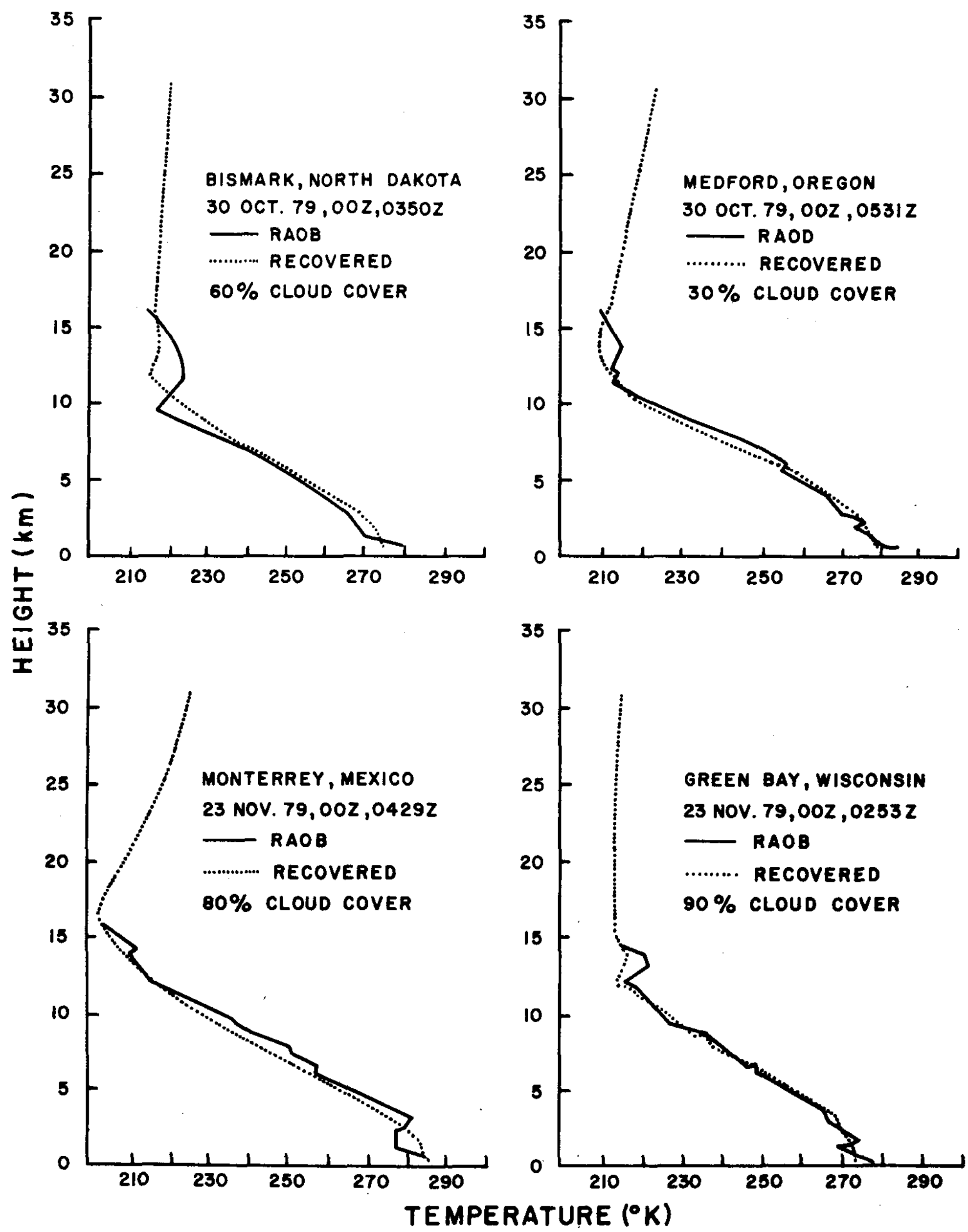

FIG. 3. As in Fig. 2 except for four cloudy cases.

temperature profiles from radiosondes are available for comparison, it is shown that the temperatures close to the surface suffer increased degradation as the rainfall rate increases. Moreover, this study also reveals that nonprecipitating clouds appear to have little effect on the microwave temperature retrieval.

Although the current study employs only four precipitating cases in the analysis and may not be conclusive in view of the limited sample used, it appears that the effect of precipitation on temperature profile retrieval using microwave frequencies is substantial and significant. Of course, the reliability of the statistical method for the temperature profile retrieval in clear atmospheres should be examined comprehensively and completely utilizing data that are available in different localities and seasons. Moreover, the error in retrieved temperatures as a function of rainfall rate should be investigated from a larger sample of carefully selected precipitation cases. Finally, means of detecting erroneous sounding data objectively must be developed so that corrections for precipitation effects may be carried out.

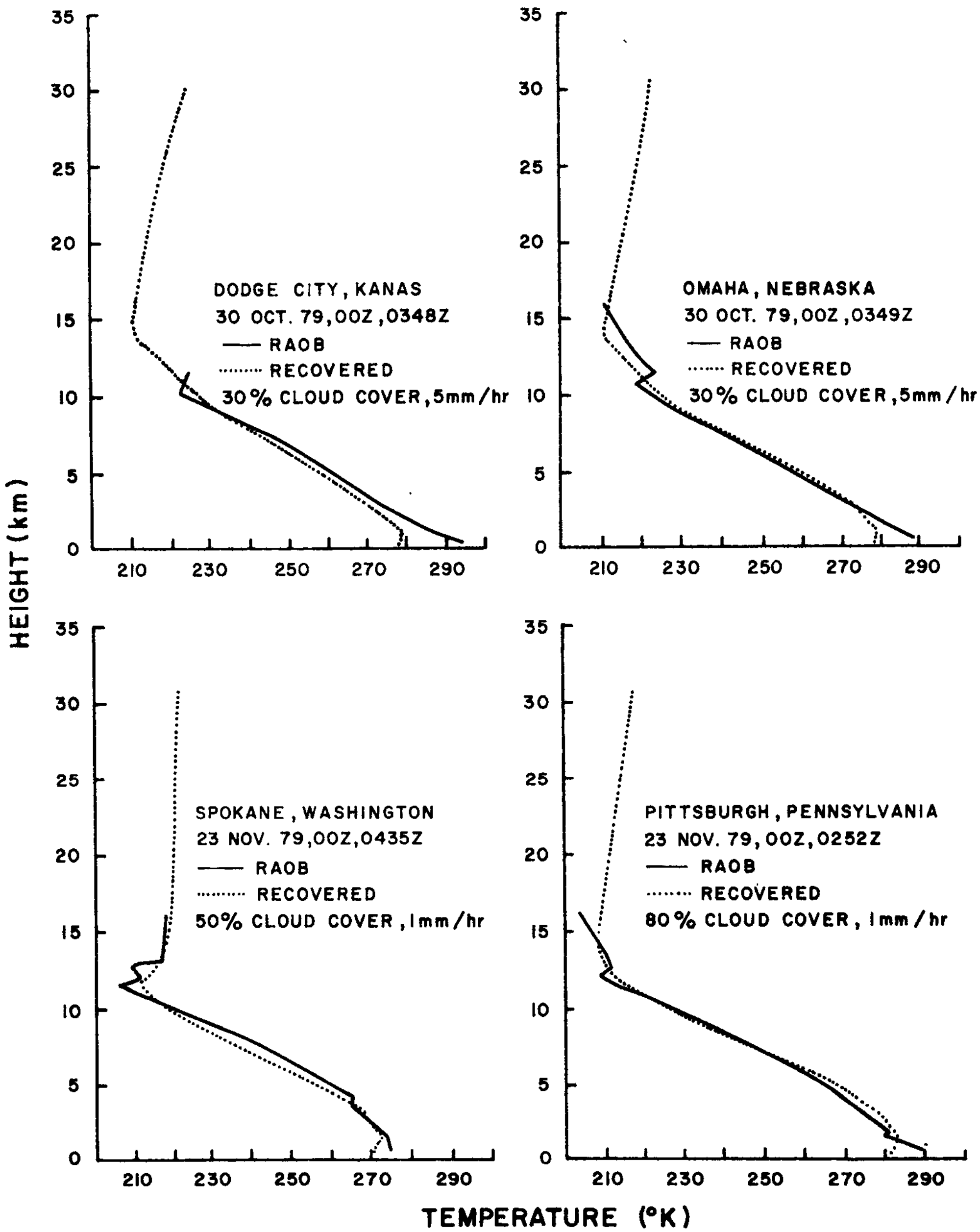

FIG. 4. As in Fig. 2 except for four precipitation cases.

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