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ADVANCED METEOROLOGICAL TEMPERATURE SOUNDER (AMTS) SIMULATIONS

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ABSTRACT

This is a report of simulation studies on temperature retrievals from AMTS and their effect on atmospheric analysis. Observations are simulated from radiosonde reports and observed cloud cover. Temperature retrievals are performed and RMS temperature and thickness errors are calculated relative to the radiosonde profiles and compared to similarly generated HIRS statistics. Significant improvement over HIRS is found throughout the atmosphere but especially in the stratosphere and lower troposphere.

INTRODUCTION

The AMTS is a next generation passive IR temperature-humidity sounder currently being designed for use on space shuttle or free flyer in a joint Goddard-JPL project. This sounder uses narrow spectral band passes in order to select spectral regions whose atmospheric absorption characteristics have pressure and temperature dependence which produce sharp temperature weighting functions (Kaplan et al., 1977). The multi-purpose sounder consists of 28 channels, shown in Table 1, which have spectral band passes ranging from 0.5–2.5 cm^{-1} and are designed to sound atmospheric temperature profile, humidity profile, surface temperature, cloud height, and cloud amount. The weighting functions for 12 temperature sounding channels are shown in Fig. 1, together with a comparable set for HIRS. The AMTS weighting functions are all considerably sharper than those of HIRS, with the exception of the channel at 635.77 cm^{-1}, peaking at 280 mb, which is of comparable sharpness to the analogous HIRS channel. The simulation study employed these channels as well as two 15μm channels in both AMTS and HIRS for cloud filtering.

SIMULATION STUDY

A simulation study was performed to assess the impact of improved temperature sounding on atmospheric analyses. Significant level temperature profiles from 73 radiosonde reports over the U. S. at 16 February 1976 were used to generate the true atmosphere. Observations for both HIRS and AMTS were simulated in two adjacent fields of view for each radiosonde station, using

Table 1. Advanced meteorological sounder spectral bands.

Channel number	Center wavelength $\nu(cm^{-1})$	$\lambda(\mu m)$	Resolution $\Delta\nu(cm^{-1})$	Main function
1	606.95	16.476	0.5	Cloud filtering
2	623.20	16.046	0.5	Cloud filtering
3	627.80	15.929	0.5	Cloud filtering
4	635.85	15.727	0.5	Temperature
5	646.60	15.466	0.5	Temperature
6	652.75	15.320	0.5	Temperature
7	666.25	15.009	0.5	Temperature
8	666.85	14.996	0.5	Temperature
9	669.25	14.942	0.5	Temperature
10	667.90	14.972	0.5	Temperature
11	1203.00	8.313	1.0	Windows and
12	1231.80	8.118	1.0	cloud filtering
13	1772.00	5.643	1.5	Humidity
14	1844.50	5.422	1.5	Humidity
15	1889.57	5.292	1.5	Humidity
16	1809.50	5.526	1.5	Humidity
17	1839.40	5.437	1.5	Humidity
18	1850.90	5.403	1.5	Humidity
19	1930.10	5.181	1.5	Humidity
20	2384.00	4.1946	2.0	Temperature
21	2386.10	4.1909	2.0	Temperature
22	2388.20	4.1873	2.0	Temperature
23	2390.20	4.1837	2.0	Temperature
24	2392.35	4.1800	2.0	Temperature
25	2394.50	4.1762	2.0	Temperature
26	2424.00	4.1254	2.5	Surface
27	2505.00	3.9920	2.5	temperature
28	2616.50	3.8219	2.5	

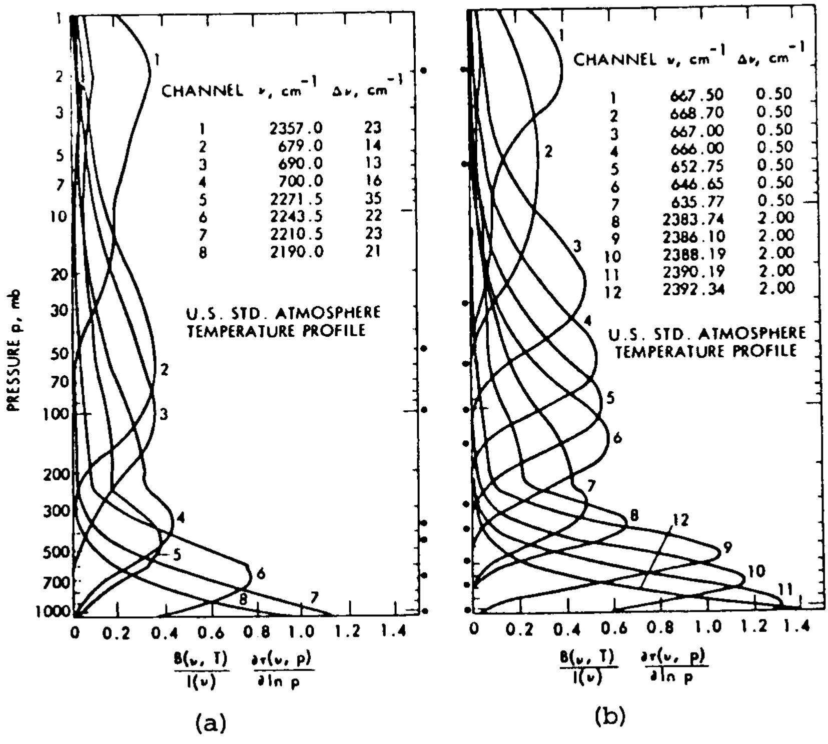

Fig. 1. Normalized weighting functions of HIRS (Fig. 1a) and AMTS (Fig. 1b) temperature sounding channels for nadir viewing.

the radiosonde profile, observed cloud cover, and a .2°C brightness temperature random noise in all channels. The observed (single layer) cloud heights and cloud fractions for each field of view were derived from HIRS/SCAMS observations over the U. S. at that time period using the dual field of view technique described in Halem et al. (1978). Temperature differences between the ground and the surface air were included in the simulation to the extent that they were included in the radiosonde significant level temperature profile. Additional surface effects such as non-unit emissivity and reflected solar radiation were not included in the simulation. Also, the effect of humidity and ozone on the transmittances were ignored though the temperature dependence of the transmittances was taken into account. Effects of humidity and ozone, non-unit emissivity, reflected solar radiation, and surface air-ground temperature discontinuities all tend to degrade the quality of actual soundings close to the ground. Thus, simulated soundings in the lower troposphere will be somewhat better than actual soundings for both HIRS and AMTS. These factors can be partially accounted for by observations in supplementary channels. However, it is expected that the effects neglected in the simulation will degrade actual AMTS lower tropospheric sounding relative to the simulation less than those of HIRS for the following reasons: First, AMTS has more water vapor sounding channels with sharper weighting functions than HIRS. Second, AMTS has three 4.0μm channels designed for use in determining ground temperature, surface emissivity, and reflected solar radiation while HIRS has one and HIRS 2 on TIROS N has two. Finally, unlike HIRS, AMTS soundings are unaffected by ozone.

RESULTS

Given the set of observations, retrievals were performed for both HIRS and AMTS, using the Chahine (1970) relaxation method and cloud filtering technique (Chahine, 1974). For comparison purposes, a climatology initial guess was used for both AMTS and HIRS. Table 2 shows RMS temperature errors of the retrieved profiles versus mandatory level radiosonde temperatures for the HIRS and AMTS retrievals. Significant improvement is seen between 500 mb and the surface and above 200 mb.

As a result of the sharpness of the AMTS weighting functions, it is also possible to perform AMTS retrievals using only the observed brightness temperatures to generate the initial guess without the benefit of any a-priori information whatsoever. This procedure uses the empirical finding that brightness temperature for AMTS channels closely approximates actual temperatures at channel-dependent characteristic pressures for a wide variety of profiles. Observed brightness temperatures are then used as initial guess temperatures at the characteristic levels. The temperature profile is obtained by linear interpolation of T ln ln P between the characteristic pressures in all segments except one in which a discontinuity in apparent lapse rate occurs.

Table 2. RMS temperature errors (°C) at mandatory levels.

Pressure (mb)	HIRS	AMTS guess	
		Climatology	Characteristic pressure
50	3.14	2.17	2.22
70	4.26	2.07	1.83
100	3.06	1.65	1.58
150	2.34	1.48	2.11
200	4.76	4.01	2.45
240	2.47	2.52	2.45
300	1.90	1.91	2.69
400	1.77	1.65	1.63
500	1.73	1.36	.88
700	2.32	1.55	1.45
850	2.08	1.54	1.60
1000	.92	.69	.72
Overall	2.77	2.04	1.89

The temperature profile in this segment, assumed to contain the tropopause, is determined by triangulation from adjacent segments. The intersection of the adjacent segments provides a good measure of the tropopause and agrees in height with the actual tropopause to better than 1 Km.

Results of AMTS retrievals using characteristic pressure guess including triangulations are shown in the last column of Table 2. These retrieved temperatures are at least as good over all as those using the climatology guess, though temperatures at 300 mb are somewhat worse due to the relative broadness of the 300 mb weighting function.

The effects of the higher resolving power of the AMTS over HIRS is demonstrated by a sample retrieval shown in Fig. 2. Fig. 2a shows the radiosonde profile together with the retrieved HIRS profile using a climatology guess. While general agreement is good, detailed changes in lapse rate in the lower troposphere and tropopause region are poorly represented in the solution. The same radiosonde station is compared to the AMTS profile retrieved using the characteristic pressure guess. Agreement of the retrieved profile with the radiosonde profile is substantially better than for HIRS, particularly in the lower troposphere and tropopause region. The derived tropopause agrees to within 3 mb with the actual tropopause pressure.

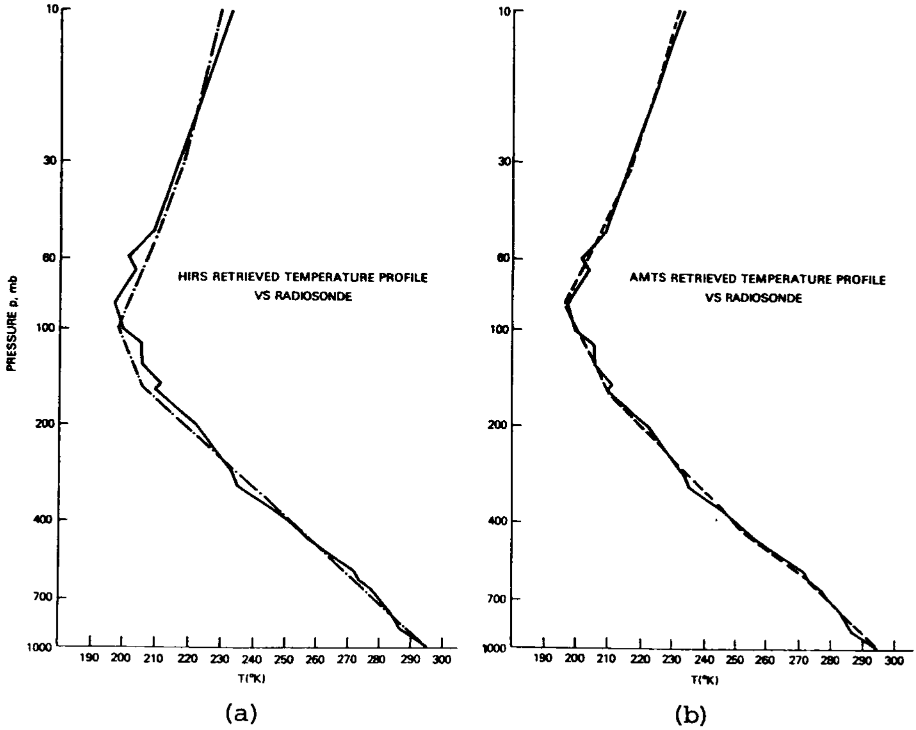

Fig. 2. Sample radiosonde significant level temperature profile with superimposed retrieval of HIRS and AMTS.

Table 3 shows RMS errors of retrieved slab-averaged temperatures between the mandatory pressure levels as compared to slab-averaged radiosonde temperatures. These thickness errors are more significant meteorologically than point temperature differences. As with the temperature errors, the thickness errors are in all cases smaller in AMTS than HIRS when a climatology guess is used. Use of the characteristic pressure guess produces further substantial improvement in the middle troposphere, but degradation around 300 mb. Work is still being done to improve results in this region.

Table 3 also shows RMS errors of the mean temperatures between 500 mb and the surface relative to radiosonde. These are approximately 1°C in HIRS, .5°C in AMTS with climatology guess, and .25°C in AMTS with characteristic pressure guess, corresponding to mean errors of 20, 10, and 5 meters in 500 mb heights, respectively. The significance of these errors can best be seen in contours of 500 mb heights constructed from radiosonde temperatures and compared to those constructed from the AMTS and HIRS retrievals. While HIRS agreement is good, the AMTS duplicates almost all structure of the radiosonde 500 mb height field. These fields, as well as those of thickness and tropopause, will be shown in the oral presentation.

Table 3. RMS slab average temperature errors (°C).

Slab (mb)	HIRS	AMTS guess: Climatology	AMTS guess: Characteristic pressure
1-50	2.06	.58	.15
50-100	3.36	1.05	1.01
100-200	2.00	1.24	1.37
200-300	1.44	1.29	1.87
300-400	1.67	1.45	1.88
400-500	1.54	1.35	.97
500-700	1.18	.98	.62
700-850	1.76	.91	.86
850-Surface	1.46	1.05	1.14
Overall (mass weighted)	1.65	1.10	1.09
500-Surface	.96	.47	.23

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