2A.10 A NEW ERA IN GLOBAL TEMPERATURE MONITORING WITH THE ADVANCED MICROWAVE SOUNDING UNIT (AMSU)

Roy W. Spencer *
NASA Marshall Space Flight Center
Global Hydrology and Climate Center
Huntsville, Alabama

William D. Braswell
Nichols Research Corporation
Global Hydrology and Climate Center
Huntsville, Alabama

John R. Christy
The University of Alabama in Huntsville
Global Hydrology and Climate Center
Huntsville, Alabama

1.0 INTRODUCTION

The launch of the first Advanced Microwave Sounding Unit (AMSU) on the NOAA-15 spacecraft on 13 May 1998 marked a significant advance in our ability to monitor global temperatures. Compared to the Microwave Sounding Units (MSU) flying since 1978 on the TIROS-N series of NOAA polar orbiters, the AMSU offers better horizontal, vertical, and radiometric resolutions. It will allow routine monitoring of 11 (mostly) separate layers, compared to 2 or 3 with the MSU, including layers in the middle and upper stratosphere (2.5 hPa) where increasing carbon dioxide concentrations should be causing a cooling rate of about 1 deg. C per decade. More precise limb corrections combined with low noise will allow identification of subtle spatial temperature patterns associated with global cyclone activity. (Spencer et al., 1995).

2.0 AMSU INSTRUMENT CHARACTERISTICS

The AMSU-A package is a fifteen channel temperature sounder operating at frequencies from 23.8 to 89.0 GHz, while the AMSU-B unit is a five channel humidity sounder with frequencies from 89 GHz to 183.3 GHz. Only the AMSU-A unit will be discussed here. Because microwave antenna designs are typically diffraction limited, the beamwidth, and therefore the spatial resolution, scales linearly with channel frequency. In order to correct for this dependence, the AMSU-A unit has three separate antenna systems designed to provide nearly the same spatial resolution (50 km, as opposed to 110 km for the MSU) at all frequencies. It scans cross-track and samples 30 footprints (as opposed to the MSUs' 11), and successive scan lines are separated by 50 km (as opposed to 150 km for the MSU). The AMSU-A characteristics are listed in Table 1. The temperature sensitivities (noise) are averages of laboratory measured values of three copies of AMSU. The higher peaking weighting functions have increasingly narrow bandwidths, causing greater measurement noise. The AMSU-A was extensively tested and characterized by the manufacturer, Aerojet. The calibration viewing modes (warm targets and the cosmic background) of the instrument utilized metallic shrouds to improve antenna coupling and reduce sidelobe effects.

*Corresponding author address: Roy W. Spencer, NASA/MSFC/GHCC, 977 Explorer Blvd, Huntsville, Alabama 35806; roy.spencer@msfc.nasa.gov

TABLE 1. AMSU-A characteristics

Chan. No.	Frequency (GHz)	Noise (deg. C)	Wgt. Fn. Peak
1	23.8	0.17	Surface
2	31.4	0.23	Surface
3	50.3	0.25	Surface
4	52.8	0.15	900 hPa
5	53.596	0.15	600 hPa
6	54.4	0.14	400 hPa
7	54.94	0.14	250 hPa
8	55.5	0.15	150 hPa
9	v_1=57.290344	0.17	90 hPa
10	v_1 +/- 0.217	0.22	50 hPa
11	v_1 +/- 0.3222 +/- 0.048	0.24	25 hPa
12	v_1 +/- 0.3222 +/- 0.022	0.36	10 hPa
13	v_1+/- 0.3222 +/- 0.010	0.48	5 hPa
14	v_1+/- 0.3222 +/- 0.0045	0.80	2.5 hPa
15	89.0	0.15	surface

3.0 TEMPERATURE MONITORING PRODUCTS

3.1-*Troposphere and Stratosphere*

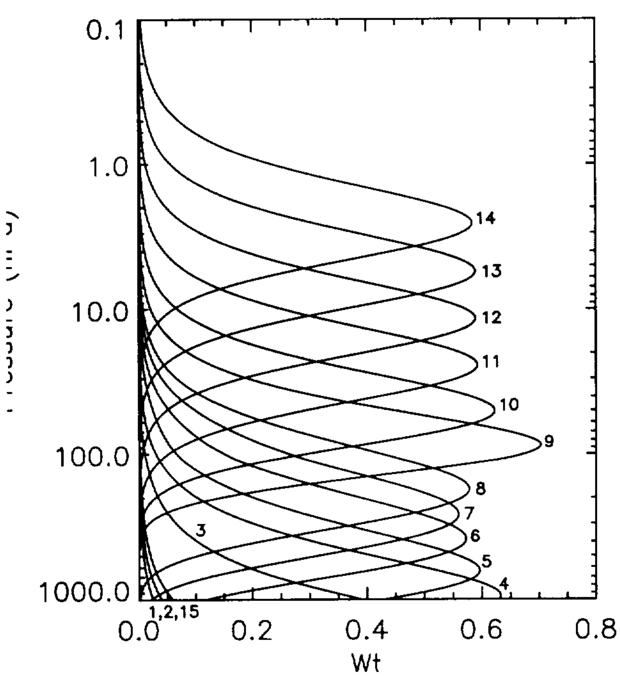
The traditional use of data obtained by a microwave or infrared temperature sounder involves the retrieval of an atmospheric temperature profile that matches the satellite measurements to within some measurement accuracy. Unfortunately, because this is an ill-posed inversion problem, there are an infinite number of profiles that would produce the same set of brightness temperatures (Tb). The profile chosen depends upon certain constraints, containing additional information, placed on the retrieval problem. As far as we know, these constraints are always dominated by weather (not climate) variations, usually from radiosondes. Since we do not know what the vertical structures of climate change will look like, we have decided to not use constraints that impose weather-related information on the retrievals.

Instead, we have chosen to continue the alternative method of utilizing the individual channels as measures of deep-layer weighted average temperatures, where the weights are represented by the weighting function profiles in Fig. 1 (e.g. Spencer and Christy, 1990) .

Fig. 1 Weighting functions (δτ/δlnp) for the atmospheric contribution to the AMSU-A channels, nadir view.

Somewhat higher vertical resolution than these profiles provide can be achieved by linear weighted differences of overlapping profiles, resulting in sharper "averaging kernels" (Conrath, 1972; Goldberg and Fleming, 1995). As a baseline, we will monitor the eleven layers represented by channels 4 through 14. A user of these datasets could then combine the channels in different ways depending upon their needs.

3.2-*Surface*



It is not yet clear whether land surface temperatures can be monitored from the AMSU-A surface channels. Because even small variations in microwave surface emissivity (ε) can cause substantial changes in Tb (3 deg. C for ε change of 0.01), it might be difficult to monitor surface temperatures with sufficient precision to identify a global warming signal (0.2 deg C/decade). One possibility we are exploring is to utilize all of the surface-sensitive channels together to retrieve surface emissivity as a separate parameter, thereby improving the retrieval of surface temperature. It is unlikely that sea surface temperatures (SST) will be monitored with the AMSU-A because most of its channels have almost no Tb sensitivity to SST change.

4.0 LIMB CORRECTIONS

The weighting functions shown in Fig. 1 are for the nadir view only. As the AMSU-A scans away from nadir, these weighting functions peak progressively higher in the atmosphere, due to a greater path length through the atmosphere. This causes the familiar "limb darkening" problem, and inhibits interpretation of the data.

We have found that a linear combination of several channels in the vicinity of the desired channel (all at the same angle) can provide a close match to the nadir weighting function. The following approach seemed to produce global imagery with the best fidelity and lowest amount of residual limb-correction errors.

Calibration of the AMSU-A Tb was based upon the procedure developed and described by Mo (1996). The full set of TIGR radiosonde profiles (Chedin *et al.,* 1985) was employed with a radiative transfer code to produce a set of simulated AMSU brightness temperatures. Only the centers of the channel bands (or sub-bands) were utilized in these computations. Horizontally and vertically polarized Tb were computed for each channel frequency at the Earth-incidence angles corresponding to the AMSU scan geometry and the NOAA-15 altitude. Computations were made separately for (1) an ocean surface with zero wind speed, and (2) a land surface with an assumed emissivity of 0.95. In the case of the ocean simulations, rotation of the polarization state of the antenna system during scanning was accounted

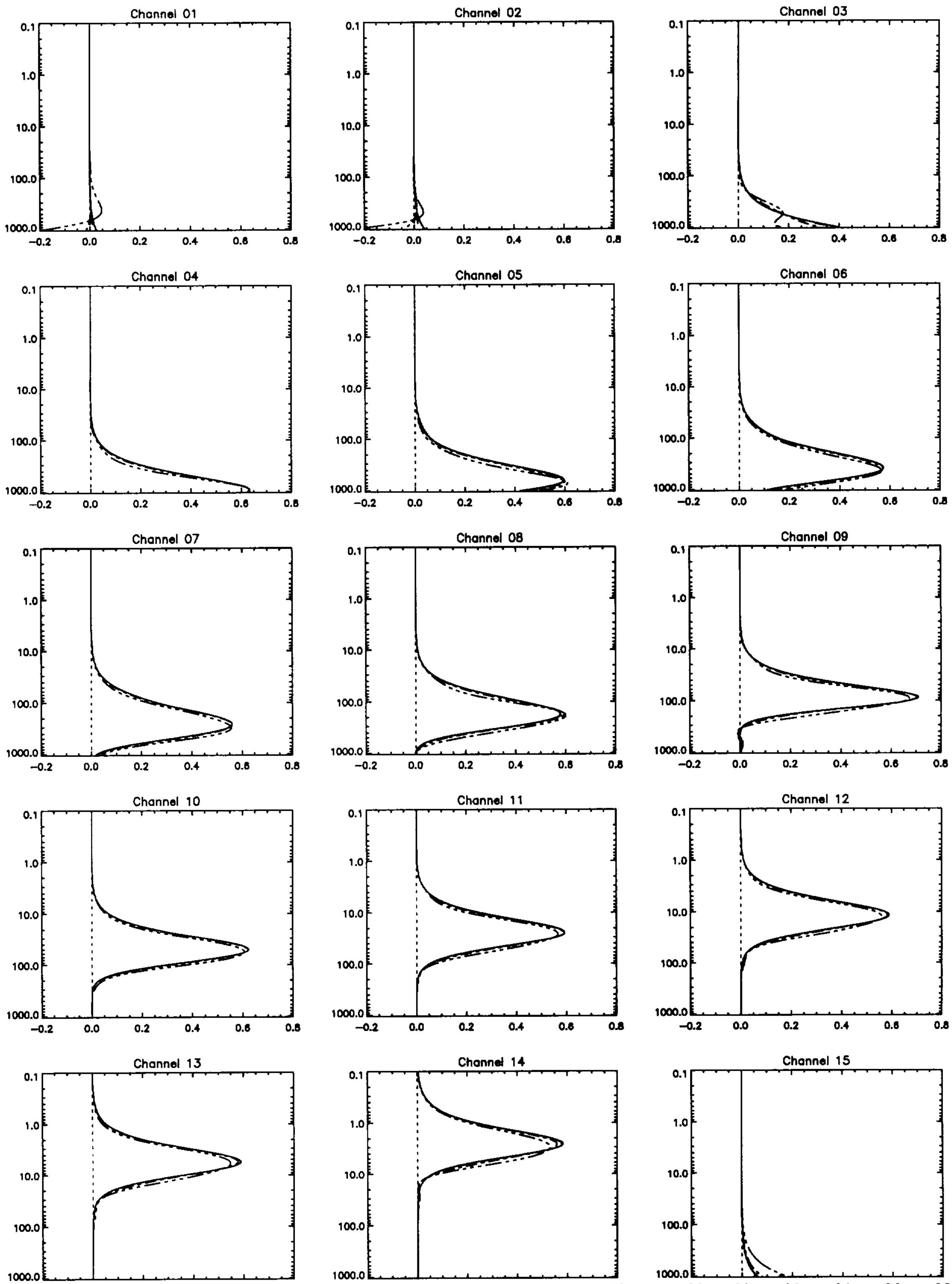


Fig. 2 AMSU-A nadir weighting functions (solid) and limb correction averaging kernels (dot-dashed) for Earth incidence angles of 17.0^{o} (footprint positions 11 & 20); 36.38^{o} (6 & 25), and 57.58^{o} (1 & 30) Due to the goodness of fit, only the extreme angle (57.58^{o}) can be seen in all panels.

for. A linear regression was performed of the nadir view Tb's for a given channel against non-nadir Tb's from the same channel as well as from several adjacent channels. The resulting regression equation coefficients can then be applied to the non-nadir weighting functions to yield the fitted, limb-corrected averaging kernel weighting functions. Figure 2 compares the resulting limb-corrected weighting functions to the nadir weighting functions. Note that the limb corrections for the near-surface channels do not necessarily provide matching sensitivities to the atmosphere, since these channels are more sensitive to surface than atmospheric emissions. As a final step, empirical footprint-position dependent residual biases had to be removed. These were computed from the limb-corrected AMSU-A data in 10 degree latitude bands, with time averaging of at least ten days being required. The biases are deviations from the scan line (30 footprint) average, so that the scan line average Tb is not changed. Based upon our experience with the MSU, these biases will likely need to be updated on at least a monthly basis. The biases were as large as 5 deg. C in the surface channels, and generally less than 1 deg. C in the sounding channels. The biases are likely contributed to by some combination of imperfections in the microwave oxygen absorption theory, sea water emissivity theory, surface emissivities different from those assumed in the simulations, problems in radiometer design and manufacture, and calibration errors.

5.0 SAMPLE IMAGERY

Sample AMSU-A limb corrected imagery will be shown during the oral presentation of this paper.

6.0 REFERENCES

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