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## NOAA Technical Report NESDIS 92



# **CALIBRATION OF THE ADVANCED MICROWAVE SOUNDING UNIT-A RADIOMETERS FOR NOAA-L AND NOAA-M**

Washington, D.C.  
May 1999

**U.S. DEPARTMENT OF COMMERCE**  
**National Oceanic and Atmospheric Administration**  
National Environmental Satellite, Data, and Information Service



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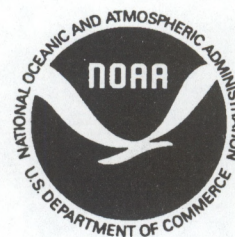
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Tsan Mo

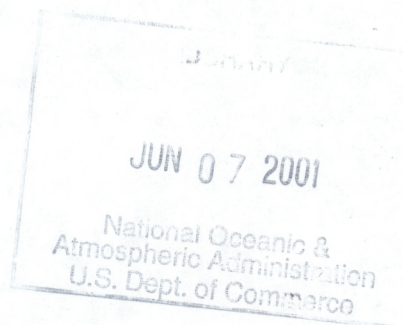
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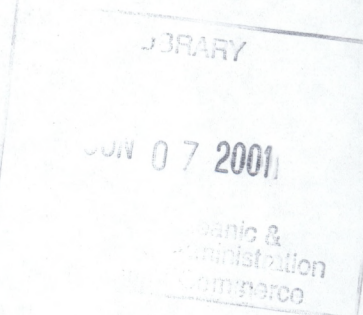
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# **CALIBRATION OF THE ADVANCED MICROWAVE SOUNDING UNIT-A RADIOMETERS FOR NOAA-L AND NOAA-M**

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## **ABSTRACT**

After the successful launch of NOAA-K into a morning-configuration orbit in May 1998, NOAA will launch its next two satellites, NOAA-L and -M, in 2000 and 2002, respectively, into afternoon-configured orbits. Both will carry the Advanced Microwave Sounding Unit-A (AMSU-A) radiometers. This report is primarily concerned with the analysis and evaluation of the thermal-vacuum chamber calibration data from the AMSU-A radiometers for both NOAA-L and -M. These pre-launch test data were analyzed to evaluate the instrument performance, including calibration accuracy, nonlinearity, and temperature sensitivity. We studied the instrument's radiometric characterizations and obtained the Calibration Parameters Input Data Set (CPIDS) which will be used for pre-launch readiness tests and post-launch operations to produce the AMSU-A 1B data sets. Particularly, the nonlinearity parameters which will be used for correcting the nonlinear contributions from an imperfect square-law detector were determined from this data analysis. The existence and magnitude of nonlinearity in each channel were established and simulated with a quadratic formula for modeling the nonlinear contributions developed in the analysis of the NOAA-K pre-launch calibration data. The model was characterized by a single parameter  $u$ , values of which were obtained for each channel via least-squares fit to the data. We performed a series of simulated in-orbit quadratic corrections which would be expected from the in-orbit data after the launch of AMSU-A into space. In these simulations, the cosmic background radiance corresponding to a cold space temperature 2.73K was adopted as one of the two reference points of calibration. The largest simulated nonlinear correction is about 0.3K. Experience learned from examining the NOAA-15 AMSU-A data provides us with a better understanding of the AMSU-A performance in space. Samples of NOAA-15 AMSU-A 1B data are included to demonstrate the orbital variations of the calibration coefficients, radiometric calibration counts, and channel gains as a function of instrument temperature.



## 1. INTRODUCTION

On 13 May 1998, the NOAA-K, which is designated NOAA-15 after the launch, was successfully launched into a circular, near-polar orbit with an altitude of 833-km above the Earth and an inclination angle of  $98.7^\circ$  to the Equator. NOAA-15 carries the first of a series of new microwave total-power radiometers, the Advanced Microwave Sounding Units (AMSU-A and AMSU-B), which provide 20 channels for atmospheric temperature and moisture soundings.

The AMSU-A component consists of two modules, AMSU-A1 and AMSU-A2. The AMSU-A1 module uses two independent antenna-radiometer systems (A1-1 and A1-2) to provide 12 channels in the range of 50.3 to 57.3 GHz oxygen band for retrieving the atmospheric temperature profiles from the Earth's surface to about 42 kilometers (or 2 mb), and another channel at 89 GHz. The AMSU-A2, which has 2 channels at 23.8 and 31.4 GHz, are used to identify precipitation and correct for surface emissivity, atmospheric liquid water, and water vapor effects. These window channels are also used to derive rain rate, sea ice concentration, and snow cover.

The U. K. Meteorological Office provides the AMSU-B for humidity sounding. It has two channels at 89 and 150 GHz, respectively, and three channels around the 183 GHz water vapor line, details of which has been described elsewhere [2].

Table 1 lists some of the NOAA-L AMSU-A channel characteristics, including channel frequency, number of bands, 3-dB RF band width, and radiometric temperature sensitivity ( $NE\Delta T$ ) for each channel. More detailed information on the AMSU-A radiometers is reported elsewhere [1]. Each of the AMSU-A antenna systems is required to have a nominal field-of-view (FOV)  $3.3^\circ$  at the half-power points and to cover a cross-track scan of  $\pm 48^\circ 20'$  (to beam centers) from the nadir direction with 30 Earth FOVs per scan line. Beam positions 1 and 30 are the extreme scan positions of the Earth views, while beam positions 15 and 16 are near the nadir direction. Onboard calibration by viewing the cold space and a blackbody target is performed once every 8 seconds for each scan line.

NOAA has built three AMSU-A flight models, namely the Protoflight Model (PFM) S/N 102, Flight Model 1 (FM1) S/N 103, and Flight Model 2 (FM2) S/N 104. GenCorp/Aerojet Electronic Systems Division is the AMSU-A contractor. Two additional flight model sets for NOAA-N and -N' are being built. The NOAA-L will carry AMSU-A1 S/N 102 (PFM) and AMSU-A2 S/N 103 (FM1), whereas NOAA-M AMSU-A consists of AMSU-A1 S/N 104 (FM2) and AMSU-A2 S/N 104 (FM2).



**Table 1. NOAA-L : Channel characteristics and specifications of AMSU-A2 FM1 and AMSU-A1 PFM .**

| Channel Number | Channel Frequency (MHz) |                  | No. of Bands | Measured 3-dB RF Bandwidth (MHz) | NEAT (K) |          | Beam # | Polarization (NADIR) | FOV** (deg.) | Remarks  |
|----------------|-------------------------|------------------|--------------|----------------------------------|----------|----------|--------|----------------------|--------------|----------|
|                | Specification           | Measured *       |              |                                  | Spec.    | Measured |        |                      |              |          |
| 1              | 23800                   | 23800.11         | 1            | 250.90                           | 0.30     | 0.166    | 96%    | V                    | 3.42         | A2 FM1   |
| 2              | 31400                   | 31400.58         | 1            | 161.40                           | 0.30     | 0.203    | 97%    | V                    | 3.52         | "        |
| 3              | 50300                   | 50299.7          | 1            | 161.16                           | 0.40     | 0.227    | 96%    | V                    | 3.60         | A1-2 PFM |
| 4              | 52800                   | 52800.74         | 1            | 380.50                           | 0.25     | 0.138    | 96%    | V                    | 3.55         | "        |
| 5              | 53596 ± 115             | 53595.47 ± 115   | 2            | 168.26   168.26                  | 0.25     | 0.154    | 96%    | H                    | 3.54         | "        |
| 6              | 54400                   | 54399.78         | 1            | 380.60                           | 0.25     | 0.131    | 96%    | H                    | 3.47         | A1-1 PFM |
| 7              | 54940                   | 54940.77         | 1            | 380.62                           | 0.25     | 0.133    | 96%    | V                    | 3.47         | "        |
| 8              | 55500                   | 55499.54         | 1            | 310.16                           | 0.25     | 0.142    | 96%    | H                    | 3.59         | A1-2 PFM |
| 9              | fo = 57290.344          | fo = 57290.334   | 1            | 310.60                           | 0.25     | 0.157    | 96%    | H                    | 3.40         | A1-1 PFM |
| 10             | fo ± 217                | fo ± 217         | 2            | 76.69   76.69                    | 0.40     | 0.210    |        | H                    |              | "        |
| 11             | fo ± 322.2 ± 48         | fo ± 322.2 ± 48  | 4            | 34.49 / 34.64   34.64 / 34.49    | 0.40     | 0.235    |        | H                    |              | "        |
| 12             | fo ± 322.2 ± 22         | fo ± 322.2 ± 22  | 4            | 15.01 / 15.31   15.31 / 15.01    | 0.60     | 0.344    |        | H                    |              | "        |
| 13             | fo ± 322.2 ± 10         | fo ± 322.2 ± 10  | 4            | 7.90 / 7.97   7.97 / 7.90        | 0.80     | 0.477    |        | H                    |              | "        |
| 14             | fo ± 322.2 ± 4.5        | fo ± 322.2 ± 4.5 | 4            | 2.89 / 2.93   2.93 / 2.89        | 1.20     | 0.768    |        | H                    |              | "        |
| 15             | 89000                   | 88999.80         | 1            | 1994.04                          | 0.50     | 0.152    | 98%    | V                    | 3.29         | "        |

\* At temperature 18 degree C.

\*\* Specification is required to have 3.3 degrees ± 10% for all channels.

# Measured.



Each of the flight models were tested and calibrated in a thermal-vacuum (TV) chamber by the contractor. NOAA scientists evaluate and analyze these pre-launch calibration data to derive the CPIDS, which is used in the NOAA operational calibration algorithm to produce the AMSU-A 1B data sets. Particularly, the nonlinearity parameters which are used for correcting the nonlinear contributions from an imperfect square-law detector must be extracted from the pre-launch calibration data.

The present study was undertaken to analyze and evaluate the TV chamber test data from two sets of AMSU-A instruments, which will be launched aboard NOAA-L and -M, respectively. The same procedure developed for NOAA-K AMSU-A calibration [1] was closely followed in this study. Experience gained from examining the NOAA-15 AMSU-A on-orbit data provides a better understanding of the AMSU-A performance in space and helps improve our analysis of the pre-launch calibration data. Samples from NOAA-15 AMSU-A 1B data are presented to demonstrate the dynamic features of the calibration coefficients and calibration counts as a function of instrument temperature.

In the following sections, we present the results of our data analysis. Specification topics evaluated in this analysis include calibration accuracy, nonlinearity, and radiometric temperature sensitivity (or  $NE\Delta T$ , the noise-equivalent uncertainty temperature). Section 2 presents a brief description of the TV chamber test data. The calibration algorithm is described in section 3. The NOAA-L results are presented in section 4, while Appendix B has the NOAA-M results. Conclusion and discussion are in section 5. Tables of CPIDS for NOAA-L and -M are given in Appendices A and B, respectively. A brief description of the NOAA Level 1B data is given in Appendix C, which also includes some samples of NOAA-15 AMSU-A 1B data which demonstrate the orbital variations of calibration coefficients, RF Shelf and Mux temperatures, calibration counts, and channel gains.

## 2. DESCRIPTION OF CALIBRATION DATA

Aerojet, the AMSU-A contractor, took the calibration data in a TV test chamber using the full scan mode. In this mode, AMSU-A scans through 30 scene-view (or beam) positions, the cold target, and the internal warm blackbody target once every 8 seconds. It takes one sample at each Earth scene position and two samples at the cold and warm targets, respectively. Since the scene calibration target was fixed at beam position 6 ( $31^{\circ}40'$  from nadir), only radiometric counts from the beam



**Table 2. Number of PRTs in each calibration target and channels provided by individual antenna systems. The last row gives the number of scans collected in the calibration for each system.**

| Items                | AMSU Antenna Systems |              |              | Remarks     |
|----------------------|----------------------|--------------|--------------|-------------|
|                      | A2                   | A1-2         | A1-1         |             |
| PRTs in Warm Target  | 7                    | 5            | 5            |             |
| PRTs in Cold Target  | 11                   | 7            | 7            |             |
| PRTs in Scene Target | 11                   | 7            | 7            |             |
| Channels             | 1 & 2                | 3, 4, 5, & 8 | 6, 7, & 9-15 |             |
| PLLO#2               | -                    | -            | Ch. 9-14     | Backup PLLO |
| N(Scan No.)          | 120                  | 400 to 900   | 400 to 900   | See Note    |

Note: For A1-1 & A1-2: N=400, 400, 550, 725, 725, and 900 when the scene target temperature at  $T_s=84, 130, 180, 230, 280,$  and  $330K$ , respectively.

position 6 can be used for calibration. Each antenna system looks at its own individual cold, warm, and scene targets. A series of Platinum Resistance Thermometers (PRTs) were used to monitor the temperatures of these calibration targets. The numbers of PRTs used to measure the physical temperatures of the scene, cold, and warm calibration targets in each antenna system are given in Table 2, which also lists the channels provided by each AMSU-A antenna system. Channels 9-14 have both primary and secondary phase locked loop oscillators (called PLLO #1 and PLLO #2, respectively) built-in. The PLLO #2 will be used for backup if PLLO #1 fails. Invar high-Q cavity stabilized local oscillators [3] are used in other channels.

The physical temperatures of scene and cold targets measured by individual PRTs were provided in Kelvin (K) on Aerojet's data tape. However, the signals from the PRTs monitoring the warm blackbody targets are given in counts, which are proportional to the blackbody temperatures. One should note that the scene and cold targets used in the TV chamber will not be carried into space. The PRT counts from warm blackbody targets must be converted to PRT temperatures. The normal approach of deriving the PRT temperatures from counts is a two-step process: (1) the resistance of



each PRT in ohms is computed by a count-to-resistance look-up table provided by the manufacturer. In this study, we used a polynomial representation of the count-to-resistance relationship provided by Aerojet; and (2) the individual PRT temperature in degrees Celsius is obtained from an analytic PRT equation [4], which is described in Appendix A. However, the two steps can be compressed to a single step with negligible errors. This single step process, which is currently used in the NOAA-15 operation, computes the PRT temperatures directly from the PRT counts, using a cubic polynomial

$$T_k = \sum_{j=0}^3 f_{kj} C_k^j \quad (1)$$

where  $T_k$  and  $C_k$  represent the temperature and count of the PRT  $k$ . The polynomial coefficients,  $f_{kj}$ , are obtained for each PRT in this study. Equation (1) also applies to 47 other housekeeping temperature sensors, such as the mixers, the IF amplifiers and the local oscillators. These  $f_{kj}$  coefficients for all PRTs and housekeeping sensors in AMSU-A1 PFM and AMSU-A2 FM1 are listed in Appendix A (Tables A-1 and A-2, respectively), while the corresponding ones for the NOAA-M AMSU-A1 FM2 and AMSU-A2 FM2 are listed in Appendix B.

The mean internal blackbody temperature,  $T_w$ , is calculated from the individual PRT temperatures,

$$T_w = \frac{\sum_{k=1}^m w_k T_k}{\sum_{k=1}^m w_k} + \Delta T_w \quad (2)$$

where  $m$  represents the number of PRTs for each antenna system (as listed in Table 2) and  $w_k$  is a weight assigned to each PRT. The quantity  $\Delta T_w$  is a warm load correction factor, which is derived for each channel from the TV test data at three RF Shelf temperatures which are defined as the instrument temperatures. The procedure for determining  $\Delta T_w$  values has been described elsewhere [5]. For each AMSU-A antenna system, a special set of calibration data was taken to determine the  $\Delta T_w$  values, which are given in Appendix A (Table A-3). The  $w_k$  value, which equals 1 (0) if the PRT  $k$  is determined good (bad) before launch.

Similarly, the mean temperatures of scene and cold targets are defined in the same way as in Equation (2), except without the term  $\Delta T_w$ .



The TV calibration data were taken at three instrument temperatures at each of which the scene target was sequenced through six temperatures 84, 130, 180, 230, 280, and 330K, respectively. At each of the scene target temperatures, calibration data were acquired for sufficient number of scans to assure an effective temperature sensitivity less than 0.03K. The number of scans required depends upon the expected NE $\Delta$ T of channel 14 (which has the largest NE $\Delta$ T) and is therefore a function of the scene target temperature. Actual numbers of scans taken at individual temperatures are given in Table 2. The uncertainties in knowledge of brightness temperatures and measurement errors were obtained by Aerojet [6, 7]. These are given Table 3.

Table 3. Uncertainty in brightness temperatures and measurement errors.

| Source of Error | AMSU-A2 :Ch. 1 and 2 |             | AMSU-A1: Ch. 3 - 15 |             |
|-----------------|----------------------|-------------|---------------------|-------------|
|                 | Bias (K)             | Random (k)  | Bias (K)            | Random (k)  |
| Warm Target     | -0.050               | $\pm 0.122$ | -0.050              | $\pm 0.122$ |
| Cold Target     | 0.024                | $\pm 0.105$ | 0.024               | $\pm 0.091$ |
| Scene Target    | 0.002                | $\pm 0.101$ | 0.002               | $\pm 0.090$ |

Antenna beamwidths at all channels were determined from the antenna patterns and the measured values for NCAA-L are listed in Table 1. Antenna beam efficiency at each channel frequency is greater than 95% as shown in Table 1.

### 3. CALIBRATION ALGORITHM

In this study, radiometric measurements and variables related to the calibration process are given in radiance with dimension of mW/(m<sup>2</sup>-sr-cm<sup>-1</sup>), instead of temperature. This is necessary because all other instruments flown on NOAA satellites produce measurements in radiance. Conversion between brightness temperature and radiance was performed using the full Planck function (not the Rayleigh-Jeans approximation). This also eliminates any possible conversion inaccuracy that may occur, particularly in the region of the space cosmic back-ground temperature  $\sim 2.73$ K, where the Rayleigh-Jeans approximation breaks down.



For each scan, the blackbody radiometric counts  $C_w$  are the averages of two samples of the internal blackbody. Similarly, the space radiometric counts  $C_c$  are the average of two samples of the space target. To reduce noise in the calibrations, the  $C_x$  (where  $x=w$  or  $c$ ) for each scan line were convoluted over several neighboring scan lines according to a weight function [8]

$$\overline{C}_x = \frac{1}{n+1} \sum_{i=-n}^n \left( 1 - \frac{|i|}{n+1} \right) C_x(t_i) \quad (3)$$

where  $t_i$  (when  $i \neq 0$ ) represents the time of the scan lines just before or after the current scan line. If  $t_0$  is the time of the current scan line, one can write  $t_i = t_0 + i\Delta t$ , where  $\Delta t = 8$  seconds for AMSU-A. The  $2n+1$  values are equally distributed about the scan line to be calibrated. Following the study of the NOAA-K AMSU-A [1], the value of  $n=3$  is chosen for all AMSU-A antenna systems. This produces the seven weights of 0.25, 0.5, 0.75, 1.0, 0.75, 0.5, and 0.25, respectively, from the weight factor that is defined within the parentheses in Equation (3) for the seven scans  $i = -3, -2, -1, 0, 1, 2$ , and 3.

A calibration algorithm, which takes into account the nonlinear contributions due to an imperfect square-law detector, converts scene counts to radiances. The calibration algorithm [1,2] developed for NOAA-K AMSU-A and -B is used in this study to obtain the scene radiance  $R_s$ . It is given by

$$R_s = R_w + (R_w - R_c) \left( \frac{C_s - \overline{C}_w}{\overline{C}_w - \overline{C}_c} \right) + Q, \quad \frac{mW}{m^2-sr-cm^{-1}} \quad (4)$$

where  $R_w$  and  $R_c$  are the radiances computed from the PRT blackbody temperature  $T_w$  and the PRT cold target temperature  $T_c$ , respectively, using the Planck function. The  $C_s$  is the radiometric count from the scene (Earth) target. The averaged blackbody and space counts,  $\overline{C}_w$  and  $\overline{C}_c$ , are defined by Equation (3). The quantity  $Q$ , which represents the nonlinear contribution, is given by [1]

$$Q = u (R_w - R_c)^2 \frac{(C_s - \overline{C}_w)(C_s - \overline{C}_c)}{(\overline{C}_w - \overline{C}_c)^2} \quad (5)$$

where  $u$  is a free parameter, values of which are determined at three instrument temperatures (extreme low, nominal, and extreme high). After launch of the instruments, the  $u$  values at the actual on-orbit instrument temperatures will be interpolated from these three values. For channels 9-14



(AMSU-A1-1), two sets of the  $u$  parameters are provided; one set is for the primary PLLO#1 and the other one for the redundant PLLO#2.

The quantity  $R_s$  defined in Equation (4) represents the radiometric scene radiances observed at individual channels. For users of NOAA Level 1B data, a simplified formula, which converts  $C_s$  directly into  $R_s$ , is presented in Appendix C. It should be noted that the ratios in Equations (4) and (5) will eliminate the effect of any channel gain variation on  $R_s$ . The channel gain,  $G$ , is defined as

$$G = \frac{\overline{C_w} - \overline{C_c}}{R_w - R_c}, \quad \frac{\text{Count} \cdot (m^2\text{-sr-cm}^{-1})}{mW} \quad (6)$$

The quantity  $G$  varies with instrument temperature, which is defined as the RF Shelf temperature for each AMSU-A antenna system. For a fixed instrument temperature,  $G$  is constant. The first two terms in Equation (4) constitute a linear two-point calibration equation if the quadratic term is negligible. Let  $R_{sL}$  denote these two terms,

$$R_{sL} = R_w + (R_w - R_c) \left( \frac{C_s - \overline{C_w}}{\overline{C_w} - \overline{C_c}} \right), \quad \frac{mW}{m^2\text{-sr-cm}^{-1}} \quad (7)$$

We first calculate the radiometric scene radiances  $R_{sL}$  from the TV chamber test data, using this two-point calibration equation. The results are given in the following section.

## 4. RESULTS

### 4.1 Calibration Accuracy

The calibration accuracy,  $\Delta R$ , is defined as the difference between the PRT measured scene radiance,  $R_{spt}$ , and the radiometric scene radiance. It is calculated from the equation

$$\Delta R = \frac{1}{N} \sum_{i=1}^N (R_{spt} - R_{sL})_i \quad (8)$$



where  $N$  is the number of scans at individual scene temperatures ( $N= 120$  for AMSU-A2 channels but ranging from 400 to 900 for AMSU-A1 channels).

Equation (7) would be a good representation of the microwave radiometric scene radiance from a perfect square-law detector. Any deviation of the quantity  $R_{sl}$  from the measured scene radiance  $R_{spt}$  indicates the presence of either nonlinearity in the radiometer system or some other potential source of contamination in the calibration data.

Figure 1 shows the calculated calibration accuracies versus the PRT scene radiances ( $R_{spt}$ ) for channels 1 through 15. The quantities along the ordinates on the left-hand sides of these plots represent the calculated  $\Delta R$  values from Equation (8), while the corresponding differences in temperature,  $\Delta T$  (K), are shown on the right-hand side. The PRT scene temperatures,  $T_{spt}$ , ranging from 84K (the lowest data point) to 330K (the highest data point) are shown on the upper abscissas. The AMSU-A specification requires  $\Delta T = 2.0K$  for channels 1, 2, and 15, and  $\Delta T = 1.5K$  for all other channels. The results in Figure 1 are much less than the specification at all channels.

It is interesting to note that pattern of the  $\Delta R$  values (Figure 1) is polarization dependent. Channels 1-4, 7, and 15 are vertically polarized at nadir, whereas other channels are horizontally polarized. Figure 1 shows that the  $\Delta R$  patterns of vertically polarized channels (with exceptions for Channels 7 and 15) are different from those of the horizontally polarized channels. Similar patterns of polarization-dependence in calibration accuracy are also observed in AMSU-B calibration data [2]. Evidence indicates that the combination of non-unity surface reflectance of the antenna reflector and polarization mixture at off-nadir scan angles produces these polarization-dependent  $\Delta R$  patterns in calibration accuracy [9].

## 4.2 Nonlinearity

The  $\Delta R$  patterns at certain channels (Figure 1) show clearly the nonlinearity forms which can be represented by the quadratic formula  $Q$  defined in Equation (5). Patterns of  $\Delta R$  at other channels are not so obvious. The nonlinearity of a channel is normally defined as the residuals from a least-squares fit of its scene PRT radiances as a linear function of the radiometric radiances  $R_{sl}$  (Equation 7). The nonlinearity is defined as the differences (or residuals) between the  $R_{spt}$  and the best-fit results from a linear equation in the form  $LinFit = a + bR_{sl}$  (where  $a$  and  $b$  are the intercept and slope). These residuals, which are denoted by  $Q (= R_{spt} - LinFit)$  are shown in Figure 2. The largest



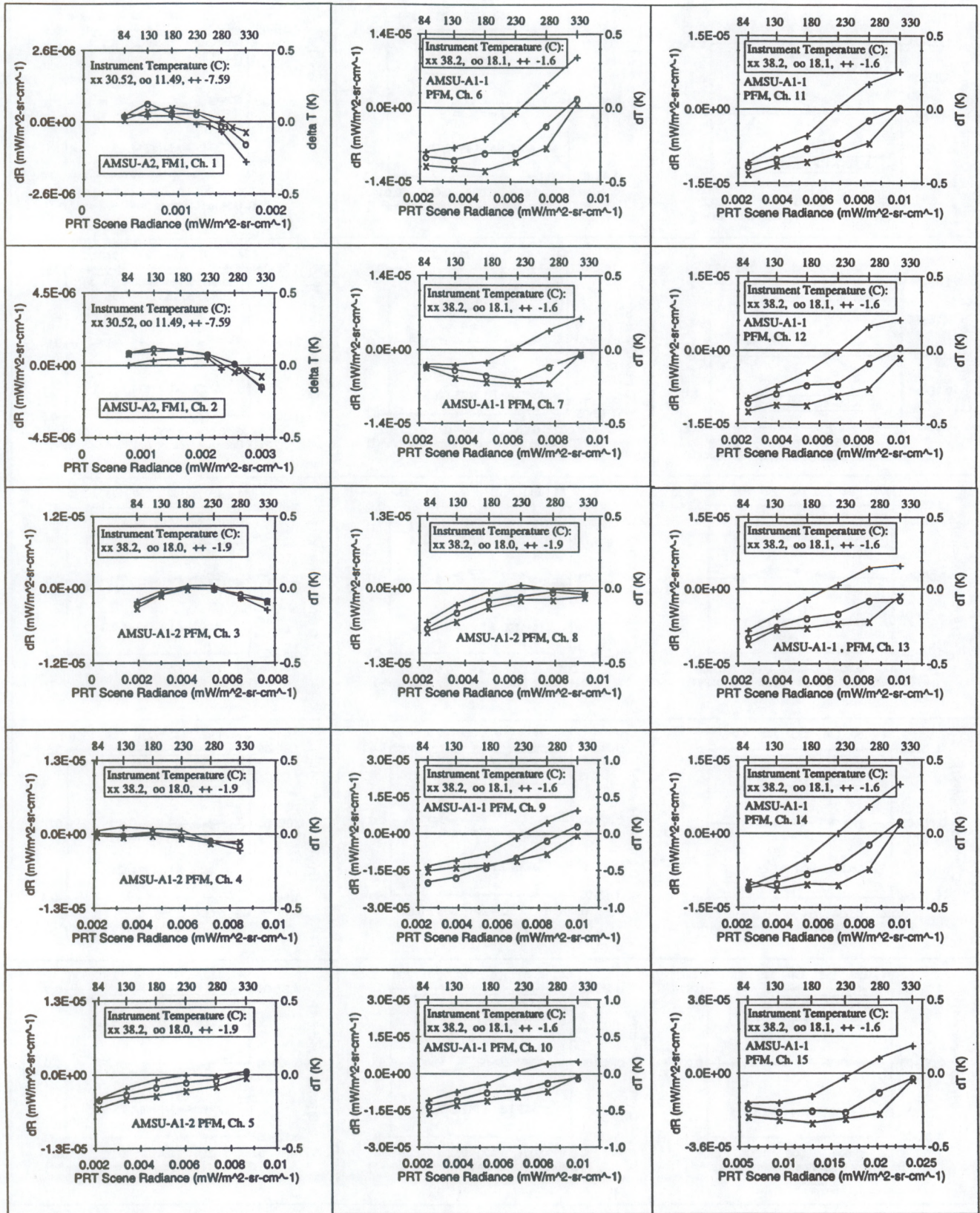


Figure 1. NOAA-L AMSU-A : Calibration accuracies at three instrument temperatures.



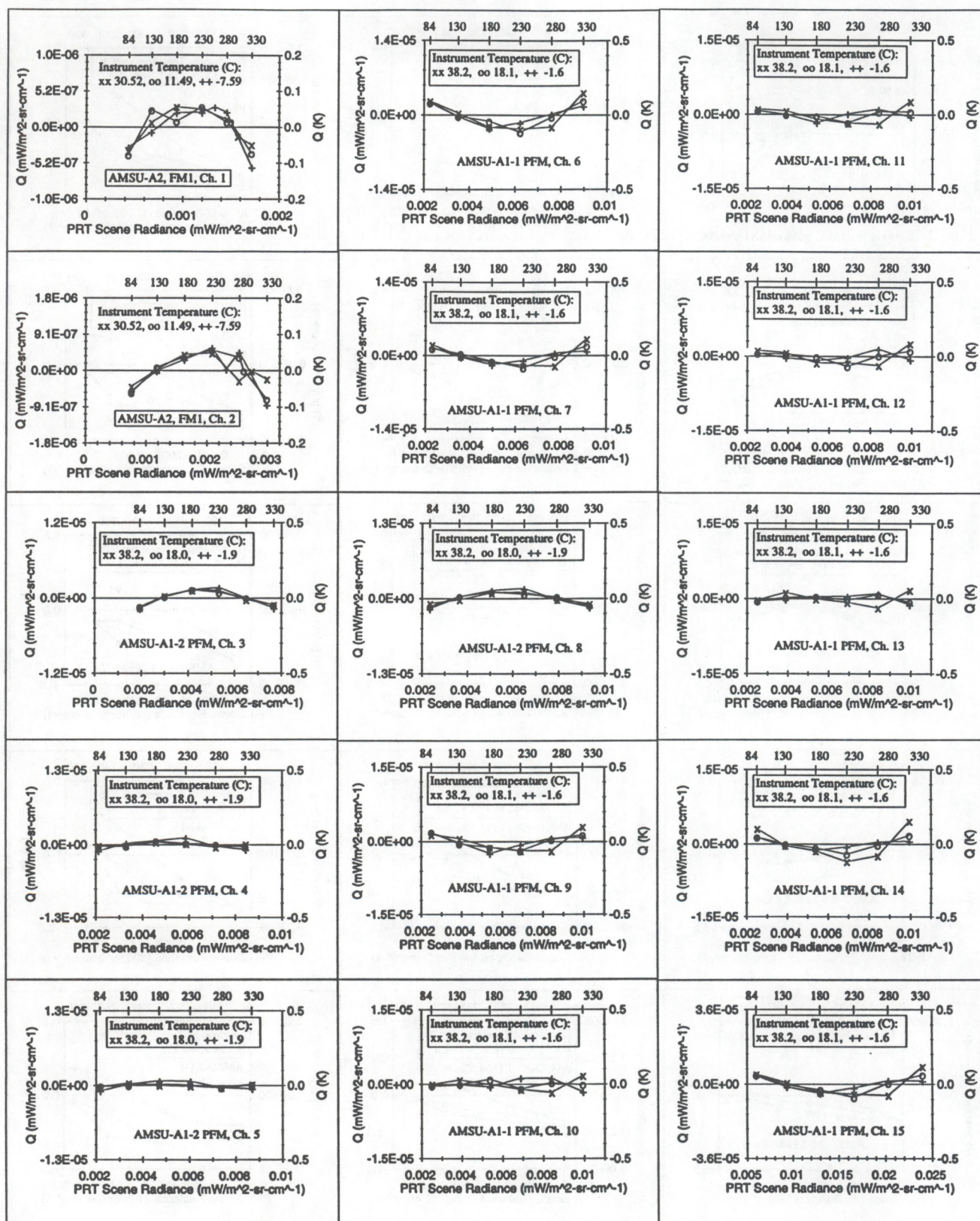


Figure 2. NOAA-L AMSU-A : Residuals after least-squares fit of the PRT scene radiances as a function of RsL as defined in Equation (7).



(absolute) Q value on each curve is defined as its nonlinearity.

The results in Figure 2 show that the maximum (absolute) Q values are about 0.1K. The AMSU-A specification requires  $Q = 0.5K$  for channels 1, 2, and 15; and  $Q = 0.375K$  for other channels. Results in Figure 2 satisfy the specifications at all channels. Most of the curves in Figure 2 have two roots, representing solutions of a quadratic equation, which can be written in the form

$$Q = u(R_s - R_1)(R_s - R_2) \quad (9)$$

where  $R_1$  and  $R_2$  represent the two roots. One can obtain a similar equation from Equation (5) by replacing the counts by its individual radiances, since the radiometric counts are proportional to radiances in a first-order approximation. The resultant equation represents a straight line intersecting the curve at  $R_w$  and  $R_c$ . Once the parameter  $u$  is determined, it can be used with any pair of roots to calculate  $Q$ . We applied Equation (9) to fit the quadratic curves in Figure 2 to obtain the  $u$  values with the two roots extracted from each plot. Table 4 gives the best-fit  $u$  values at three instrument temperatures for individual channels.

#### 4.3 Simulated Quadratic Corrections to On-Orbit Data

Once the  $u$  values are determined, Equation (9) can be used to simulate the quadratic contributions which are expected from on-orbit data. This can be accomplished by replacing the roots  $R_1$  and  $R_2$  with the radiances  $R_{2.73}$  (corresponding to cold space temperature 2.73K) and  $R_w$ , respectively. The simulated results are shown in Figure 3 for all channels at three instrument temperatures which are also listed in the plots. One should note that the instrument temperatures are slightly different for the three AMSU-A antenna systems. The simulated quadratic contributions displayed in Figure 3 are larger than those shown in Figure 2. This is expected because the separation of the two reference calibration points is enlarged in the simulations. Figure 3 shows that there are little nonlinearities at channels 4, 5, and 10-13. Noticeable quadratic contributions appear at other channels. The largest ones are approximately 0.3K shown at several channels. It should be noted that the effects of instrument temperature on the quadratic contributions are nonlinear for most channels.

Similarly, Figure 4 shows the calculated results which are associated with the redundant PLL0#2 built into channels 9-14. Part (a) of Figure 4 displays the calibration accuracies,  $\Delta R$ , which are



**Table 4. Best-fit values of the nonlinearity parameters  $u$  in dimension of  $(m^2\text{-sr-cm}^{-1})/mW$ .**

| AMSU-A2 FM1 Channels: |           |           | AMSU-A1-2 PFM Channels: |           |           |           |           |
|-----------------------|-----------|-----------|-------------------------|-----------|-----------|-----------|-----------|
| Instrument Temp. (C)  | Ch 1      | Ch 2      | Instrument Temp. (C)    | Ch 3      | Ch 4      | Ch 5      | Ch 8      |
| 30.52                 | -1.470560 | -0.529709 | 38.19                   | -0.222428 | -0.012048 | -0.000184 | -0.121400 |
| 11.49                 | -1.504450 | -0.911241 | 18.03                   | -0.277188 | -0.003329 | -0.008661 | -0.193230 |
| -7.59                 | -1.294450 | -0.669055 | -1.88                   | -0.361222 | -0.126966 | -0.029753 | -0.236868 |

| AMSU-A1-1 Channels:  |          |          | PFM PLLO#1 |           |          |          |           |          |          |  |  |  |  |  |
|----------------------|----------|----------|------------|-----------|----------|----------|-----------|----------|----------|--|--|--|--|--|
| Instrument Temp. (C) | Ch 6     | Ch 7     | Ch 9       | Ch 10     | Ch 11    | Ch 12    | Ch 13     | Ch 14    | Ch 15    |  |  |  |  |  |
| 38.18                | 0.492290 | 0.378907 | 0.158709   | 0.062007  | 0.046013 | 0.054332 | 0.062201  | 0.494668 | 0.133904 |  |  |  |  |  |
| 18.09                | 0.413067 | 0.227749 | 0.165745   | -0.017056 | 0.001821 | 0.013551 | -0.054097 | 0.216822 | 0.100521 |  |  |  |  |  |
| -1.64                | 0.306440 | 0.060986 | 0.158983   | -0.094177 | 0.036557 | 0.017753 | -0.074448 | 0.095885 | 0.100327 |  |  |  |  |  |

| AMSU-A1-1 Channels:  |          |           | PFM PLLO#2 |          |           |          |  |  |  |  |  |  |  |  |
|----------------------|----------|-----------|------------|----------|-----------|----------|--|--|--|--|--|--|--|--|
| Instrument Temp. (C) | Ch 9     | Ch 10     | Ch 11      | Ch 12    | Ch 13     | Ch 14    |  |  |  |  |  |  |  |  |
| 38.24                | 0.279726 | 0.034338  | 0.192467   | 0.120489 | 0.000008  | 0.428774 |  |  |  |  |  |  |  |  |
| 17.90                | 0.218900 | 0.000477  | 0.073817   | 0.191061 | 0.011472  | 0.561697 |  |  |  |  |  |  |  |  |
| -1.75                | 0.034243 | -0.138611 | 0.015066   | 0.022001 | -0.170343 | 0.357317 |  |  |  |  |  |  |  |  |



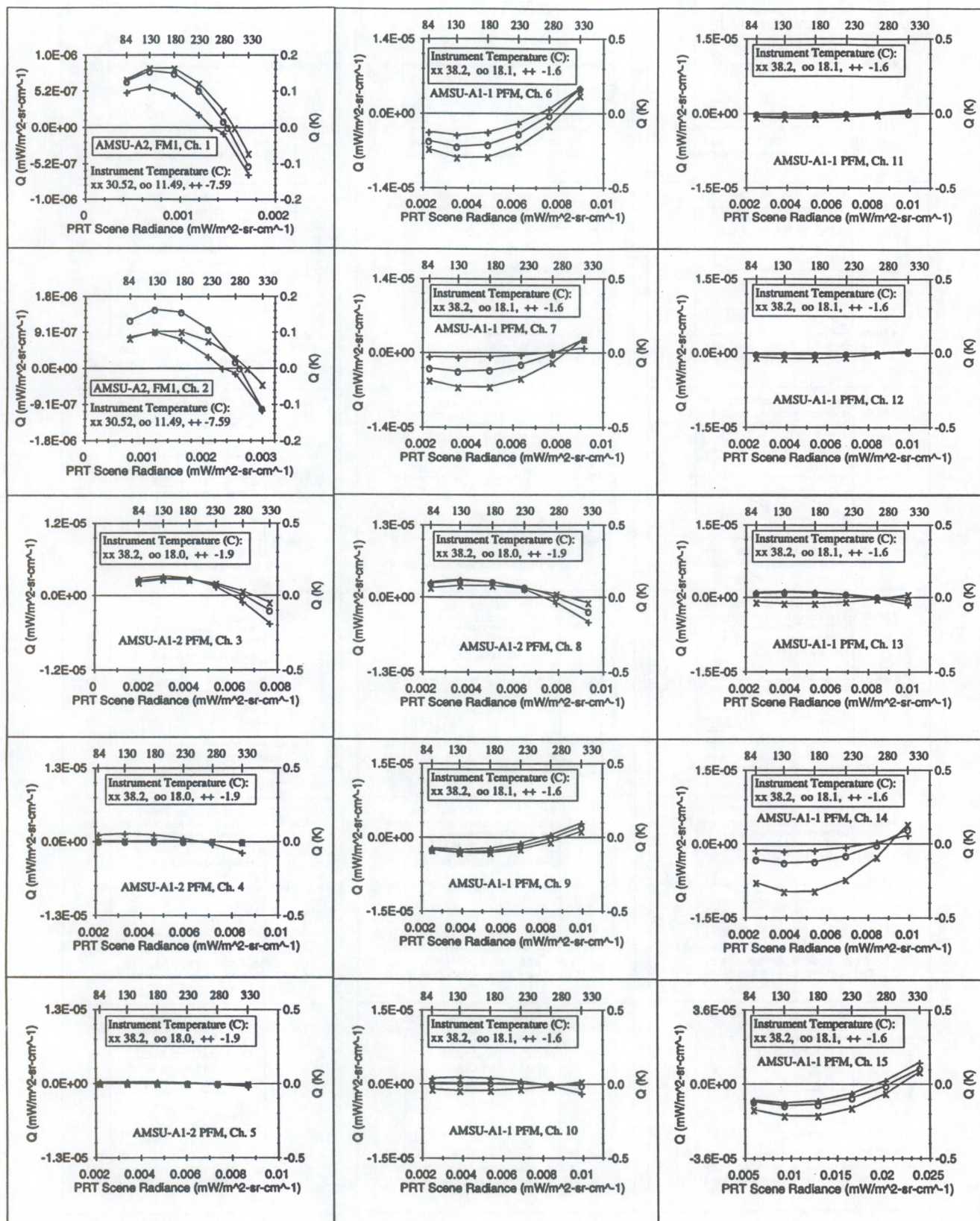


Figure 3. NOAA-L AMSU-A : Simulated nonlinear corrections as expected from in-orbit data.



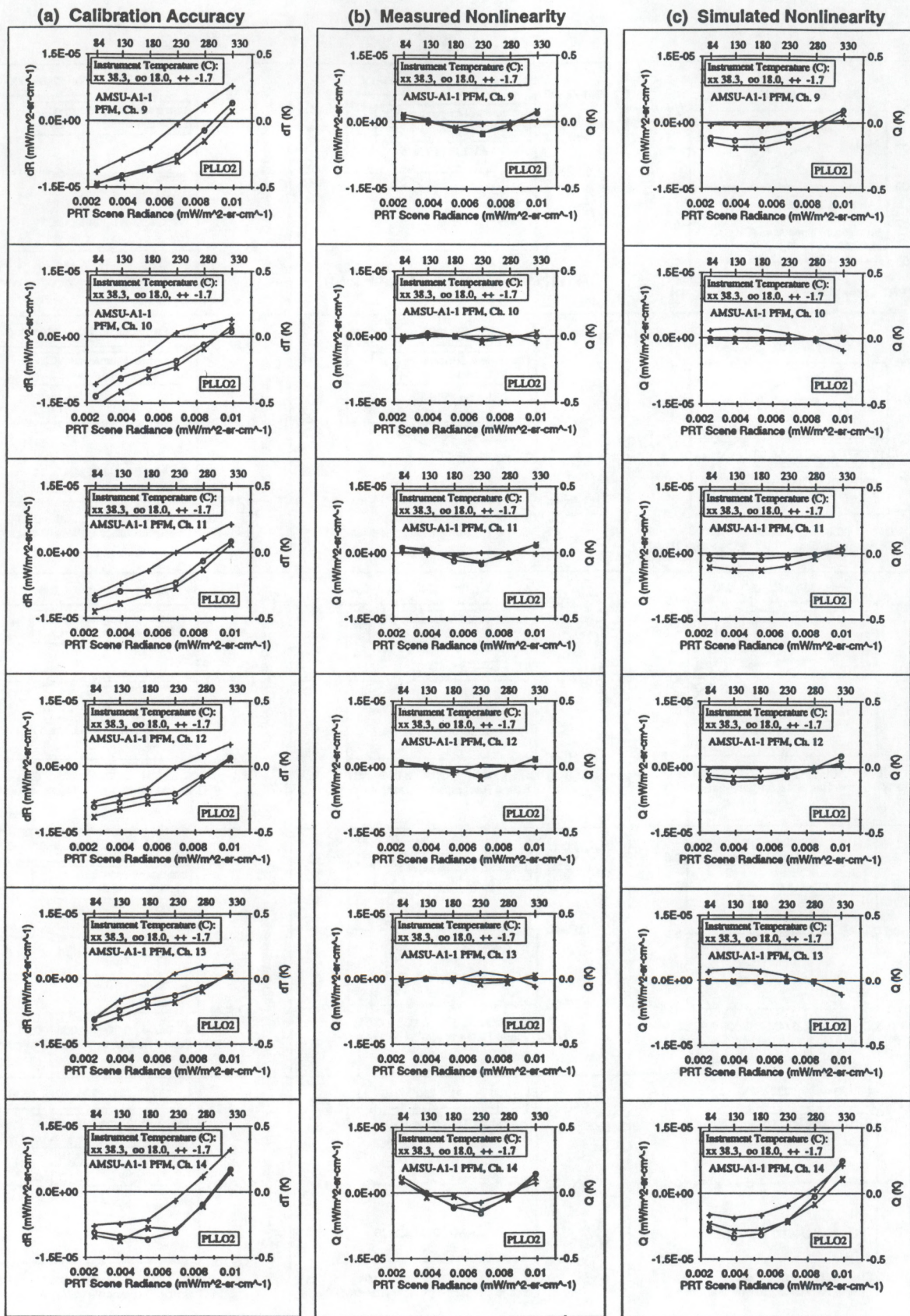


Figure 4. NOAA-L AMSU-A : Calibration results with PLL02 in Channels 9-14,  
(a) calibration accuracy, (b) measured nonlinearity, and (c) simulated nonlinearity.



similar to Figure 1, while part (b) which corresponds to Figure 2 shows the residuals of the least-squares fit. Part (c) shows the simulated quadratic corrections,  $Q$ , that are expected in space.

#### 4.4 Temperature Sensitivity

The temperature sensitivity (or  $NE\Delta T$ ) requirements for AMSU-A channels are listed in Table 1. It is defined as the minimum change of scene brightness temperature that can be detected. In practice, it is calculated as the standard deviation of the radiometer output (in K), when an antenna system is viewing a scene target at 300K. The calculated  $NE\Delta T$  values are shown in Figure 5 together with the requirements from the AMSU-A specifications. These calculated  $NE\Delta T$  values correspond to a scene temperature of 305K, because they are the average values of two measurements taken at the scene target temperatures of 280K and 330K, respectively (no calibration data were taken at 300K). All of the calculated  $NE\Delta T$  values in Figure 5 are less than those required by the AMSU-A specification. Actually, all  $NE\Delta T$  values measured at both 280 and 330K satisfy the specification.

#### 4.5 Radiometric Counts at Zero Radiance

Figure 6 shows some sample plots of radiometric counts versus the PRT temperatures taken from the AMSU-A1-1 channels. The radiometric counts consist of scene counts taken at scene target temperatures ranging from 84 to 330K. Many data points coincide to each other and cannot be distinguished in the plots. Each symbol  $x$  represents all of these data points (not averaged value at that temperature). Figure 6 shows that good linear relationships exist between the radiometric counts and the PRT temperatures in the range 84 to 330K. We can extrapolate these linear relationships to 0 K (corresponding to zero radiance) and obtain the intercepts for these plots. The intercept for each data point can also be computed from Equation (7) by setting  $R_{sL} = 0$  and solve for  $C_s$ , which is denoted by  $C_{sint}$ . Then we have

$$C_{sint} = \overline{C_w} - G R_w \quad (10)$$

where  $G$  is the channel gain defined in Equation (6). The calculated  $C_{sint}$  values at three instrument temperatures for each channel are listed in Table 5. These are the mean values of all calculations performed with all available calibration data (from 400 to 900 scans as the scene temperature varies from 84 to 330K). At each instrument temperature, the variation in the calculated  $C_{sint}$  values is



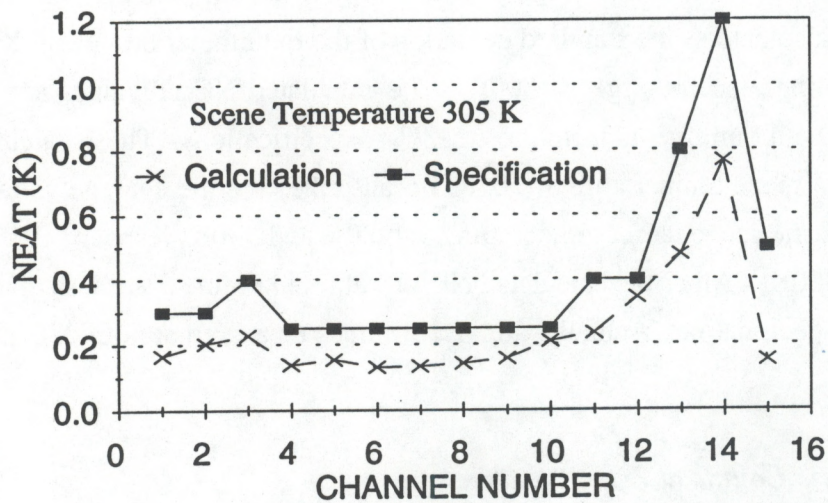


Figure 5. NOAA-L AMSU-A : Comparison of the measured NEdT values with specification.



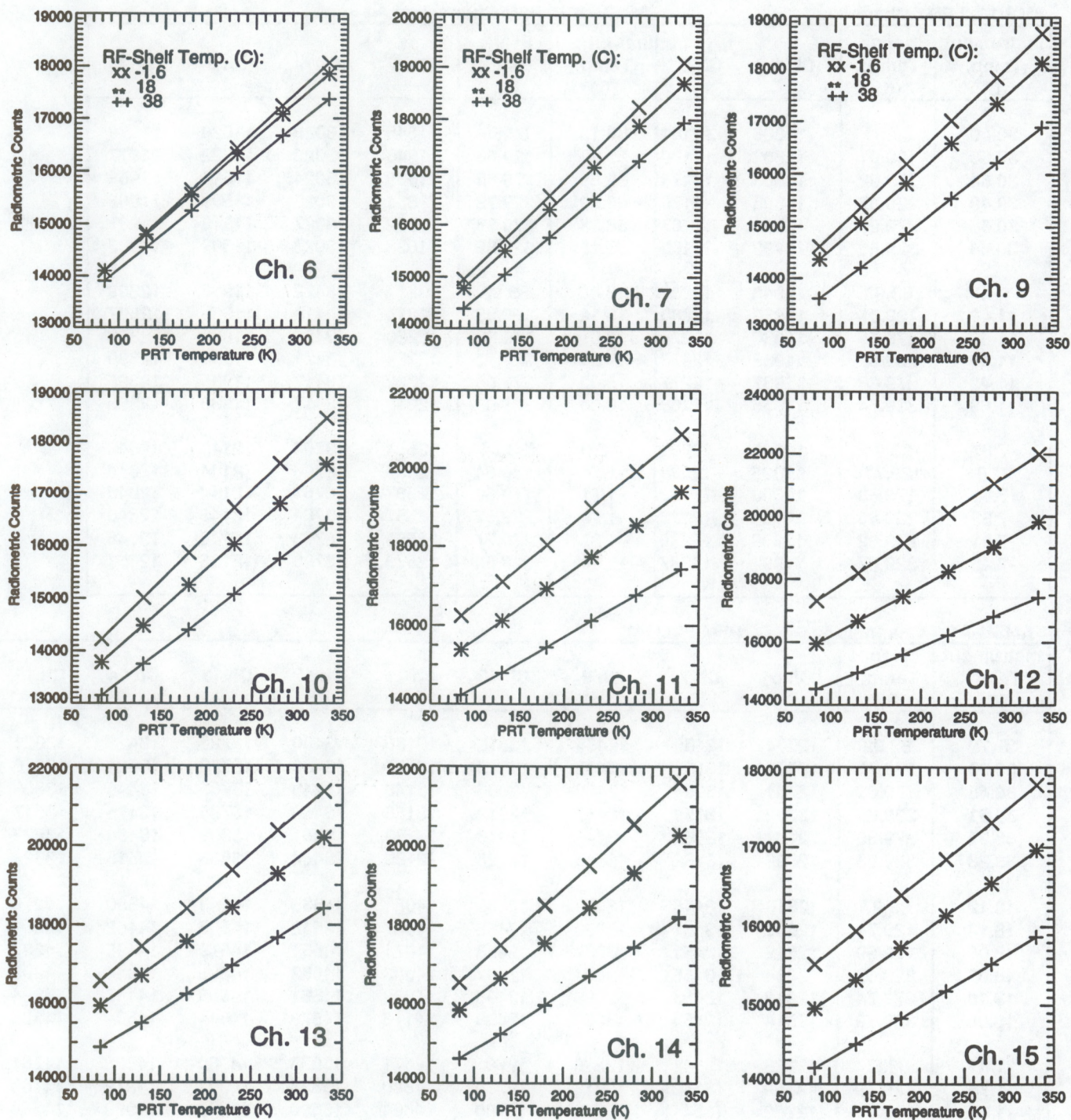


Figure 6. NOAA-L AMSU-A : Radiometric counts at three instrument temperatures versus PRT temperatures. All channels are from AMSU-A1-1 PFM.



**Table 5. NOAA-L AMSU-A Radiometric counts at zero radiances.**

| AMSU-A2 FM1 Channels: |                 |       |       | AMSU-A1-2 PFM Channels: |                 |       |       |       |       |
|-----------------------|-----------------|-------|-------|-------------------------|-----------------|-------|-------|-------|-------|
| Instrument Temp. (C)  | Scene Temp. (K) | Ch 1  | Ch 2  | Instrument Temp. (C)    | Scene Temp. (K) | Ch 3  | Ch 4  | Ch 5  | Ch 8  |
| 30.50                 | 84.01           | 11806 | 12181 | 38.10                   | 83.89           | 11645 | 13029 | 11520 | 11979 |
| 30.53                 | 129.91          | 11802 | 12170 | 37.99                   | 129.66          | 11648 | 13029 | 11522 | 11977 |
| 30.54                 | 179.92          | 11803 | 12175 | 38.35                   | 179.62          | 11636 | 13024 | 11511 | 11968 |
| 30.49                 | 229.85          | 11805 | 12170 | 38.39                   | 229.73          | 11631 | 13023 | 11509 | 11968 |
| 30.65                 | 279.90          | 11799 | 12167 | 38.13                   | 279.88          | 11632 | 13027 | 11513 | 11967 |
| 30.48                 | 329.80          | 11798 | 12169 | 38.18                   | 329.82          | 11628 | 13023 | 11509 | 11963 |
|                       |                 |       |       |                         |                 |       |       |       |       |
| 11.424                | 83.93           | 11940 | 12282 | 18.02                   | 83.93           | 12217 | 13422 | 11936 | 12399 |
| 11.49                 | 129.87          | 11939 | 12280 | 18.12                   | 129.66          | 12214 | 13419 | 11935 | 12397 |
| 11.50                 | 179.59          | 11938 | 12278 | 18.01                   | 179.63          | 12220 | 13420 | 11938 | 12398 |
| 11.46                 | 229.82          | 11938 | 12276 | 17.99                   | 229.72          | 12224 | 13421 | 11938 | 12399 |
| 11.42                 | 279.86          | 11937 | 12277 | 18.02                   | 279.64          | 12222 | 13417 | 11935 | 12395 |
| 11.69                 | 329.74          | 11935 | 12268 | 18.04                   | 329.88          | 12218 | 13417 | 11933 | 12393 |
|                       |                 |       |       |                         |                 |       |       |       |       |
| -7.67                 | 83.94           | 11995 | 12251 | -1.70                   | 83.84           | 12564 | 13754 | 12143 | 12648 |
| -7.8                  | 129.714         | 11995 | 12238 | -1.74                   | 129.64          | 12558 | 13756 | 12144 | 12648 |
| -7.64                 | 179.69          | 12000 | 12232 | -1.71                   | 179.66          | 12557 | 13761 | 12144 | 12648 |
| -7.38                 | 229.86          | 11996 | 12223 | -1.73                   | 229.62          | 12557 | 13764 | 12143 | 12646 |
| -7.51                 | 279.82          | 11990 | 12239 | -1.89                   | 279.77          | 12559 | 13773 | 12148 | 12648 |
| -7.46                 | 329.87          | 11992 | 12237 | -2.54                   | 329.90          | 12573 | 13790 | 12155 | 12651 |

| AMSU-A1-1 Channels : |                 | PFM PLLO#1 |       |       |       |       |       |       |       |       |
|----------------------|-----------------|------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Instrument Temp. (C) | Scene Temp. (K) | Ch 6       | Ch 7  | Ch 9  | Ch 10 | Ch 11 | Ch 12 | Ch 13 | Ch 14 | Ch 15 |
| 37.79                | 83.92           | 12704      | 13160 | 12454 | 12015 | 13136 | 13480 | 13721 | 13423 | 13621 |
| 38.03                | 129.70          | 12705      | 13161 | 12448 | 12015 | 13134 | 13460 | 13728 | 13421 | 13618 |
| 38.45                | 179.69          | 12701      | 13156 | 12430 | 12005 | 13146 | 13443 | 13765 | 13445 | 13608 |
| 38.31                | 229.68          | 12702      | 13159 | 12437 | 12012 | 13168 | 13460 | 13796 | 13475 | 13617 |
| 38.24                | 279.80          | 12701      | 13154 | 12441 | 12018 | 13173 | 13461 | 13809 | 13488 | 13622 |
| 38.23                | 329.93          | 12699      | 13152 | 12445 | 12025 | 13189 | 13464 | 13833 | 13515 | 13629 |
|                      |                 |            |       |       |       |       |       |       |       |       |
| 18.12                | 83.97           | 12810      | 13448 | 13079 | 12486 | 14051 | 14638 | 14542 | 14390 | 14279 |
| 18.14                | 129.74          | 12809      | 13451 | 13079 | 12488 | 14057 | 14642 | 14555 | 14402 | 14281 |
| 18.08                | 179.59          | 12812      | 13451 | 13081 | 12493 | 14071 | 14651 | 14579 | 14425 | 14287 |
| 18.02                | 229.67          | 12814      | 13455 | 13084 | 12497 | 14086 | 14662 | 14595 | 14444 | 14293 |
| 18.10                | 279.74          | 12813      | 13453 | 13083 | 12496 | 14089 | 14661 | 14605 | 14457 | 14294 |
| 18.08                | 329.99          | 12814      | 13454 | 13098 | 12498 | 14117 | 14679 | 14644 | 14504 | 14304 |
|                      |                 |            |       |       |       |       |       |       |       |       |
| -1.81                | 83.85           | 12759      | 13541 | 13220 | 12781 | 14671 | 15693 | 14980 | 14892 | 14761 |
| -1.75                | 129.79          | 12759      | 13542 | 13216 | 12780 | 14680 | 15693 | 14991 | 14912 | 14763 |
| -1.68                | 179.71          | 12762      | 13541 | 13216 | 12780 | 14684 | 15690 | 14999 | 14920 | 14764 |
| -1.57                | 229.52          | 12764      | 13542 | 13217 | 12783 | 14691 | 15690 | 15013 | 14936 | 14766 |
| -1.52                | 279.55          | 12772      | 13544 | 13222 | 12789 | 14709 | 15696 | 15049 | 14968 | 14774 |
| -1.52                | 329.95          | 12779      | 13547 | 13229 | 12795 | 14723 | 15697 | 15056 | 14990 | 14784 |



relatively small and all  $C_{\text{sint}}$  values are positive. Table 4 shows that the instrument temperature is an important factor in determining the magnitude of  $C_{\text{sint}}$ , which increases as the instrument temperature decreases, but with exceptions at channels 2 and 6.

#### **4.6 Channel gains**

Values of the channel gains as defined in Equation (6) are also calculated from the TV calibration data. The gain values are converted into dimension of count/K. Table 6 lists the calculated channel gains at three instrument temperatures, which are listed in the first column. Note that the gain of Channel 15 is smaller than those of other channels approximately by a factor 2.

### **5. CONCLUSION AND DISCUSSION**

We have analyzed the TV chamber calibration data from the NOAA-L instruments (AMSU-A1 PFM and AMSU-A2 FM1) and the NOAA-M instruments (AMSU-A1 FM2 and AMSU-A2 FM2). The results show that both sets of instruments meet the AMSU-A specification in calibration accuracy, nonlinearity, and temperature sensitivity. It was found that the calibration accuracies,  $\Delta R$ , are polarization-dependent. Vertically- polarized channels (with exceptions of Channels 7 and 15) exhibit little or very small cold biases at the lowest scene target temperature 84K, while those with horizontal polarizations have cold biases, up to 0.6K. Similar pattern of polarization-dependent cold-bias is also observed in the AMSU-B calibration data [2] and it is reported [9] that the combination of non-unity surface reflectance of the antenna reflector and the polarization mixture at off-nadir scan angles produce these biases. Further investigation in this matter is required.

The existence of nonlinearity appears at most of the channels. We used a quadratic formula to simulate these nonlinear contributions, which were characterized by a single parameter  $u$ . The  $u$  values at three instrument temperatures were obtained from the calibration data. Using the best-fit  $u$  values, we performed a series of simulated quadratic corrections which would be expected from the on-orbit data. In the simulations, the cold space radiance corresponding to 2.73K was adopted as one of the two reference calibration points (the other one is the internal blackbody radiance). The largest nonlinear correction is about 0.3K at a few channels. Others are less than 0.2K.



**Table 6. NOAA-L AMSU-A Channel gains (count/K) at three Instrument temperatures.**

**AMSU-A2 FM1 Channels:**

**AMSU-A1-2 PFM Channels:**

| Instrument Temp. (C) | Scene Temp. (K) | Ch 1  | Ch 2  | Instrument Temp. (C) | Scene Temp. (K) | Ch 3 (Count/K) | Ch 4 (Count/K) | Ch 5 (Count/K) | Ch 8 (Count/K) |
|----------------------|-----------------|-------|-------|----------------------|-----------------|----------------|----------------|----------------|----------------|
| 30.50                | 84.01           | 14.24 | 14.20 | 38.10                | 83.89           | 12.99          | 13.39          | 13.85          | 15.22          |
| 30.53                | 129.91          | 14.25 | 14.22 | 37.99                | 129.66          | 13.00          | 13.41          | 13.87          | 15.23          |
| 30.54                | 179.92          | 14.24 | 14.21 | 38.35                | 179.62          | 12.98          | 13.39          | 13.86          | 15.21          |
| 30.49                | 229.85          | 14.24 | 14.21 | 38.39                | 229.73          | 12.98          | 13.39          | 13.85          | 15.21          |
| 30.65                | 279.90          | 14.22 | 14.20 | 38.13                | 279.88          | 13.00          | 13.41          | 13.88          | 15.24          |
| 30.48                | 329.80          | 14.23 | 14.20 | 38.18                | 329.82          | 13.00          | 13.42          | 13.89          | 15.24          |
|                      |                 |       |       |                      |                 |                |                |                |                |
| 11.42                | 83.93           | 15.60 | 15.26 | 18.02                | 83.93           | 14.18          | 14.66          | 15.06          | 16.63          |
| 11.49                | 129.87          | 15.60 | 15.26 | 18.12                | 129.66          | 14.17          | 14.66          | 15.05          | 16.63          |
| 11.50                | 179.59          | 15.60 | 15.26 | 18.01                | 179.63          | 14.18          | 14.67          | 15.06          | 16.64          |
| 11.46                | 229.82          | 15.60 | 15.26 | 17.99                | 229.72          | 14.19          | 14.67          | 15.07          | 16.65          |
| 11.42                | 279.86          | 15.59 | 15.26 | 18.02                | 279.64          | 14.19          | 14.68          | 15.08          | 16.65          |
| 11.69                | 329.74          | 15.57 | 15.22 | 18.04                | 329.88          | 14.20          | 14.68          | 15.09          | 16.66          |
|                      |                 |       |       |                      |                 |                |                |                |                |
| -7.67                | 83.94           | 16.67 | 16.24 | -1.70                | 83.84           | 14.94          | 15.45          | 15.90          | 17.57          |
| -7.80                | 129.71          | 16.67 | 16.22 | -1.74                | 129.64          | 14.94          | 15.45          | 15.91          | 17.58          |
| -7.64                | 179.69          | 16.65 | 16.18 | -1.71                | 179.66          | 14.95          | 15.46          | 15.91          | 17.58          |
| -7.38                | 229.86          | 16.63 | 16.17 | -1.73                | 229.62          | 14.96          | 15.47          | 15.92          | 17.59          |
| -7.51                | 279.82          | 16.63 | 16.15 | -1.89                | 279.77          | 14.98          | 15.50          | 15.95          | 17.62          |
| -7.46                | 329.87          | 16.61 | 16.14 | -2.54                | 329.90          | 15.03          | 15.55          | 16.00          | 17.67          |

**AMSU-A1-1 Channels :**

**PFM PLLO#1**

| Instrument Temp. (C) | Scene Temp. (K) | Ch 6 (count/K) | Ch 7 (count/K) | Ch 9 (count/K) | Ch 10 (count/K) | Ch 11 (count/K) | Ch 12 (count/K) | Ch 13 (count/K) | Ch 14 (count/K) | Ch 15 (count/K) |
|----------------------|-----------------|----------------|----------------|----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 37.79                | 83.92           | 14.20          | 14.56          | 13.59          | 13.37           | 12.81           | 12.10           | 13.74           | 14.10           | 6.83            |
| 38.03                | 129.70          | 14.18          | 14.54          | 13.56          | 13.34           | 12.78           | 12.04           | 13.72           | 14.07           | 6.81            |
| 38.45                | 179.69          | 14.16          | 14.52          | 13.51          | 13.30           | 12.79           | 11.98           | 13.78           | 14.11           | 6.79            |
| 38.31                | 229.68          | 14.17          | 14.54          | 13.52          | 13.32           | 12.84           | 12.02           | 13.85           | 14.17           | 6.80            |
| 38.24                | 279.80          | 14.17          | 14.54          | 13.52          | 13.32           | 12.85           | 12.02           | 13.87           | 14.19           | 6.81            |
| 38.23                | 329.93          | 14.17          | 14.54          | 13.51          | 13.32           | 12.88           | 12.01           | 13.91           | 14.23           | 6.82            |
|                      |                 |                |                |                |                 |                 |                 |                 |                 |                 |
| 18.12                | 83.97           | 15.26          | 15.85          | 15.25          | 15.34           | 15.86           | 15.54           | 16.63           | 17.34           | 8.03            |
| 18.14                | 129.74          | 15.26          | 15.85          | 15.25          | 15.34           | 15.87           | 15.55           | 16.66           | 17.36           | 8.03            |
| 18.08                | 179.59          | 15.27          | 15.87          | 15.25          | 15.35           | 15.90           | 15.57           | 16.71           | 17.42           | 8.04            |
| 18.02                | 229.67          | 15.28          | 15.87          | 15.26          | 15.36           | 15.93           | 15.59           | 16.74           | 17.45           | 8.04            |
| 18.10                | 279.74          | 15.27          | 15.87          | 15.24          | 15.34           | 15.93           | 15.58           | 16.75           | 17.47           | 8.04            |
| 18.08                | 329.99          | 15.27          | 15.88          | 15.22          | 15.34           | 15.98           | 15.60           | 16.82           | 17.55           | 8.04            |
|                      |                 |                |                |                |                 |                 |                 |                 |                 |                 |
| -1.81                | 83.85           | 16.00          | 16.83          | 16.58          | 17.17           | 18.65           | 19.19           | 18.98           | 19.89           | 9.07            |
| -1.75                | 129.79          | 16.01          | 16.82          | 16.58          | 17.16           | 18.67           | 19.19           | 19.01           | 19.93           | 9.07            |
| -1.68                | 179.71          | 16.01          | 16.82          | 16.57          | 17.15           | 18.67           | 19.18           | 19.02           | 19.94           | 9.07            |
| -1.57                | 229.52          | 16.01          | 16.82          | 16.57          | 17.15           | 18.67           | 19.16           | 19.03           | 19.96           | 9.07            |
| -1.52                | 279.55          | 16.02          | 16.82          | 16.56          | 17.14           | 18.69           | 19.15           | 19.09           | 20.01           | 9.07            |
| -1.52                | 329.95          | 16.03          | 16.83          | 16.56          | 17.12           | 18.69           | 19.12           | 19.08           | 20.03           | 9.08            |



Experience gained from examining the NOAA-15 AMSU-A 1B data provides a better understanding of the AMSU-A performance in space and helps process these pre-launch calibration data. Samples from NOAA-15 AMSU-A 1B data are presented to demonstrate the orbital variations of the calibration coefficients, radiometric calibration counts, and channel gains as a function of instrument temperature. These are shown in Appendix C.

In general, the qualities of the calibration data are quite good. Particularly, the instrument temperatures were stabilized at pre-selected values with total variation less than  $\pm 0.5\text{K}$  during each test cycle. This renders the measured instrument nonlinearities more reliable and our analysis results confirm the high quality of the AMSU-A instruments for NOAA-L and -M, as reported by Aerojet [6,7].

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## APPENDIX A

### NOAA-L CPIDS : COEFFICIENTS OF AMSU-A1 PFM AND AMSU-A2 FM1

#### A.1 Polynomial Coefficients for Converting PRT Counts into Temperatures

The two-step process for deriving the PRT temperatures from PRT counts  $C_k$  is briefly described here. First the  $C_k$  from PRT  $k$  is converted into resistance  $r_t$  (in ohms) by a polynomial

$$r_t = \sum_{i=0}^3 A_i C_k^i \quad (\text{A-1})$$

where the coefficients  $A_i$  for individual PRTs and temperature sensors were provided by Aerojet. Once the resistance  $r_t$  is known, then one can calculate the PRT temperature  $t$  (in Celsius) from the Callendar-Van Dusen equation [4], which is given by

$$\frac{r_t}{r_o} = 1 + \alpha \left[ t - \delta \left( \frac{t}{100} - 1 \right) \left( \frac{t}{100} \right) - \beta \left( \frac{t}{100} - 1 \right) \left( \frac{t}{100} \right)^3 \right] \quad (\text{A-2})$$

where:  $r_t$  = resistance (in ohms) at temperature  $t$  ( $^{\circ}\text{C}$ ) of the blackbody target

$r_o$  = resistance at  $t = 0^{\circ}\text{C}$  (supplied by the manufacturer via Aerojet)

$\beta = 0$  for  $t > 0^{\circ}\text{C}$ , and  $0.11$  for  $t < 0^{\circ}$

$\alpha$  and  $\delta$  are constants provided by the manufacturer via Aerojet.

Calculation shows that the error is negligible by setting  $\beta = 0$  in Equation (A-2). In such case, one can solve the quadratic equation for  $t$  in terms of  $r_t$ . Then the PRT temperature in degrees Kelvin is obtained from  $t + 273.15$ . By this way, data sets of PRT temperatures versus counts for individual PRTs are computed. Then Equation (1) is applied to fit these data sets for obtaining the polynomial coefficients  $f_{kj}$  for individual PRTs and housekeeping sensors. These best-fit coefficients are listed in Tables A-1 and A-2, respectively, for AMSU-A1 PFM and AMSU-A2 FM1. Test calculations show that these polynomials are highly accurate in reproducing temperatures of PRTs and sensors.



Table A-1. AMSU-A1 PFM : Polynomial coefficients for converting  
PRT counts into temperatures.

| PRT<br>Number | Description        | fk0<br>(K) | fk1<br>(K/count) | fk2<br>(K/count <sup>2</sup> ) | fk3<br>(K/count <sup>3</sup> ) |
|---------------|--------------------|------------|------------------|--------------------------------|--------------------------------|
| 1             | Scan Motor A1-1    | 263.1048   | 1.746582E-03     | 3.623661E-09                   | 1.369088E-14                   |
| 2             | Scan Motor A1-2    | 263.1302   | 1.739546E-03     | 4.253673E-09                   | 3.104099E-15                   |
| 3             | Feedhorn A1-1      | 263.0028   | 1.744484E-03     | 3.678984E-09                   | 1.200898E-14                   |
| 4             | Feedhorn A1-2      | 263.1200   | 1.734173E-03     | 4.276342E-09                   | 3.795089E-15                   |
| 5             | RF Mux A1-1        | 262.9148   | 1.747060E-03     | 3.709252E-09                   | 1.188702E-14                   |
| 6             | RF Mux A1-2        | 263.0800   | 1.726746E-03     | 4.531111E-09                   | -2.335047E-15                  |
| 7             | L.O. CH 3          | 263.1671   | 1.740339E-03     | 4.022057E-09                   | 7.456754E-15                   |
| 8             | L.O. CH 4          | 263.0920   | 1.747047E-03     | 3.665344E-09                   | 1.296970E-14                   |
| 9             | L.O. CH 5          | 263.0454   | 1.741716E-03     | 3.730534E-09                   | 1.024042E-14                   |
| 10            | L.O. CH 6          | 263.0898   | 1.733352E-03     | 4.278257E-09                   | 3.268157E-15                   |
| 11            | L.O. CH 7          | 262.9906   | 1.742614E-03     | 3.788716E-09                   | 1.060848E-14                   |
| 12            | L.O. CH 8          | 263.0473   | 1.735541E-03     | 4.206854E-09                   | 3.447964E-15                   |
| 13            | L.O. CH 15         | 263.0027   | 1.730623E-03     | 4.316739E-09                   | 2.010024E-15                   |
| 14            | PLLO #2 CH 9-14    | 262.9975   | 1.733001E-03     | 4.377321E-09                   | 1.490138E-15                   |
| 15            | PLLO #1 CH 9-14    | 263.0136   | 1.745541E-03     | 3.516409E-09                   | 1.510316E-14                   |
| 16            | PLLO (Ref. Osc.)   | 263.0801   | 1.748622E-03     | 3.639906E-09                   | 1.354159E-14                   |
| 17            | Mixer/IF CH 3      | 263.5486   | 1.746853E-03     | 3.858628E-09                   | 9.898415E-15                   |
| 18            | Mixer/IF CH 4      | 263.0144   | 1.728921E-03     | 4.296718E-09                   | 3.332378E-15                   |
| 19            | Mixer/IF CH 5      | 262.9358   | 1.740829E-03     | 3.625233E-09                   | 1.328183E-14                   |
| 20            | Mixer/IF CH 6      | 263.2686   | 1.744092E-03     | 3.552319E-09                   | 1.495706E-14                   |
| 21            | Mixer/IF CH 7      | 262.9162   | 1.740274E-03     | 3.731835E-09                   | 1.149628E-14                   |
| 22            | Mixer/IF CH 8      | 263.0908   | 1.733742E-03     | 4.340456E-09                   | 1.859928E-15                   |
| 23            | Mixer/IF CH 9/14   | 263.1438   | 1.741307E-03     | 4.056297E-09                   | 5.597673E-15                   |
| 24            | Mixer/IF CH 15     | 263.0096   | 1.735507E-03     | 4.062961E-09                   | 6.269141E-15                   |
| 25            | IF Amp. Ch.11/14   | 263.0009   | 1.738621E-03     | 4.065791E-09                   | 6.868335E-15                   |
| 26            | IF Amp. Ch. 9      | 262.6027   | 1.737624E-03     | 3.328607E-09                   | 1.830314E-14                   |
| 27            | IF Amp. Ch. 10     | 263.0690   | 1.733676E-03     | 4.231375E-09                   | 3.440546E-15                   |
| 28            | IF Amp. Ch. 11     | 262.9727   | 1.740448E-03     | 3.930992E-09                   | 8.134020E-15                   |
| 29            | DC/DC Converter    | 264.3133   | 1.448328E-03     | 2.377704E-08                   | -3.664906E-13                  |
| 30            | IF Amp. Ch. 13     | 262.8774   | 1.746592E-03     | 3.575562E-09                   | 1.434209E-14                   |
| 31            | IF Amp. Ch. 14     | 263.3979   | 1.730730E-03     | 4.216201E-09                   | 3.358531E-15                   |
| 32            | IF Amp. Ch. 12     | 262.9459   | 1.733783E-03     | 4.098350E-09                   | 5.854667E-15                   |
| 33            | RF Shelf A1-1      | 263.2371   | 1.734655E-03     | 4.305217E-09                   | 2.367451E-15                   |
| 34            | RF Shelf A1-2      | 263.1320   | 1.742492E-03     | 3.792956E-09                   | 1.036175E-14                   |
| 35            | Detector / Pre-Amp | 263.0636   | 1.737871E-03     | 4.220619E-09                   | 4.948416E-15                   |
| 36            | A1-1 Warm Load #1  | 254.0132   | 1.639314E-03     | 5.841851E-09                   | 3.170000E-14                   |
| 37            | A1-1 Warm Load #2  | 254.1451   | 1.639949E-03     | 5.782927E-09                   | 3.263241E-14                   |
| 38            | A1-1 Warm Load #3  | 253.9949   | 1.638955E-03     | 5.800192E-09                   | 3.241972E-14                   |
| 39            | A1-1 Warm Load #4  | 254.0495   | 1.639557E-03     | 5.758033E-09                   | 3.307045E-14                   |
| 40            | A1-1 Wm Ld Center  | 254.3422   | 1.640565E-03     | 5.835780E-09                   | 3.182039E-14                   |
| 41            | A1-2 Warm Load #1  | 254.0403   | 1.639240E-03     | 5.822517E-09                   | 3.224645E-14                   |
| 42            | A1-2 Warm Load #2  | 254.0150   | 1.641987E-03     | 6.027004E-09                   | 2.537188E-14                   |
| 43            | A1-2 Warm Load #3  | 253.9847   | 1.637331E-03     | 5.863943E-09                   | 3.094957E-14                   |
| 44            | A1-2 Warm Load #4  | 253.9631   | 1.643774E-03     | 5.561980E-09                   | 3.675141E-14                   |
| 45            | A1-2 Wm Ld Center  | 254.0919   | 1.640103E-03     | 5.765712E-09                   | 3.276301E-14                   |



Table A-2. AMSU-A2 FM1 : Polynomial coefficients for converting  
PRT counts into temperatures.

| PRT<br>Number | Description      | fk0<br>(K) | fk1<br>(K/count) | fk2<br>(K/count <sup>2</sup> ) | fk3<br>(K/count <sup>3</sup> ) |
|---------------|------------------|------------|------------------|--------------------------------|--------------------------------|
| 1             | Scan Motor       | 262.9059   | 1.745177E-03     | 3.740162E-09                   | 1.106630E-14                   |
| 2             | Feedhorn         | 262.8252   | 1.747243E-03     | 3.720632E-09                   | 1.201146E-14                   |
| 3             | RF Mux           | 262.8342   | 1.743510E-03     | 3.675231E-09                   | 1.238451E-14                   |
| 4             | Mixer/IF CH 1    | 262.9289   | 1.737931E-03     | 4.153611E-09                   | 5.112200E-15                   |
| 5             | Mixer/IF CH 2    | 262.9391   | 1.749657E-03     | 3.552357E-09                   | 1.498887E-14                   |
| 6             | L.O. CH 1        | 262.9683   | 1.733527E-03     | 4.224167E-09                   | 3.904070E-15                   |
| 7             | L.O. CH 2        | 262.7933   | 1.750576E-03     | 3.499452E-09                   | 1.578765E-14                   |
| 8             | CompensatorMotor | 262.7891   | 1.743946E-03     | 3.676722E-09                   | 1.246361E-14                   |
| 9             | Sub Reflector    | 263.3698   | 1.738556E-03     | 4.230298E-09                   | 3.952702E-15                   |
| 10            | DC/DC Converter  | 262.9554   | 1.749085E-03     | 3.548661E-09                   | 1.476718E-14                   |
| 11            | RF Shelf         | 262.8239   | 1.734990E-03     | 4.235791E-09                   | 3.574724E-15                   |
| 12            | Detector PreAmp  | 262.8645   | 1.721331E-03     | 5.458057E-09                   | -2.087636E-14                  |
| 13            | Warm LdCenter    | 254.0671   | 1.687549E-03     | 6.352990E-09                   | 3.149424E-14                   |
| 14            | Warm Load #1     | 254.0359   | 1.688794E-03     | 6.334522E-09                   | 3.199376E-14                   |
| 15            | Warm Load #2     | 254.0648   | 1.690630E-03     | 6.267443E-09                   | 3.301921E-14                   |
| 16            | Warm Load #3     | 253.9251   | 1.686183E-03     | 6.376563E-09                   | 3.049575E-14                   |
| 17            | Warm Load #4     | 254.0151   | 1.689233E-03     | 6.358270E-09                   | 3.152659E-14                   |
| 18            | Warm Load #5     | 254.0011   | 1.688256E-03     | 6.361316E-09                   | 3.120399E-14                   |
| 19            | Warm Load #6     | 254.0249   | 1.686592E-03     | 6.423900E-09                   | 3.021051E-14                   |



## A.2 Warm Load Correction

The in-flight warm load correction was calculated according to a formula developed by Aerojet [8, 9]. For each AMSU-A antenna system, a special set of calibration data were acquired by setting the temperature of its variable scene target equal to that of the internal blackbody (warm) target. The physical temperature  $T_w$  of the internal blackbody target was determined from the PRT counts as described in Section 2. The radiometric temperature  $T_{wrad}$  of the blackbody (in-flight warm load) was calculated (for each scan in the data set) by the formula

$$T_{wrad} = T_{sprt} + (T_{sprt} - T_c) \left( \frac{C_w - C_s}{C_s - C_c} \right) \quad (A-3)$$

where:

- $T_{sprt}$  = PRT temperature of the variable scene target,
- $T_c$  = PRT temperature of the cold target,
- $C_w$  = the average of two radiometric counts from the warm target,
- $C_c$  = the average of two radiometric counts from the cold target, and
- $C_s$  = radiometric counts from the variable scene target.

One should note that temperatures,  $T_{sprt}$  and  $T_c$ , from the scene and cold targets are used as the two reference calibration points in Equation (A-3) and the radiometric temperature for the warm target is calculated.

The in-flight warm load correction factor  $\Delta T_w$  was computed from the formula

$$\Delta T_w = \frac{1}{N} \sum_{i=1}^N (T_{wrad} - T_w)_i \quad (A-4)$$

where  $N(=725)$  represents the number of scans in the data set. The  $\Delta T_w$  values at three instrument (RF Shelf) temperatures for each AMSU-A antenna system are listed in Table A-3. For Channels 9-14 (in AMSU-A1-1), the  $\Delta T_w$  values for both PLLO#1 and PPLO#2 were calculated and listed. These  $\Delta T_w$  values will be used in NOAA-L AMSU-A operations.



**Table A-3. NOAA-L AMSU-A warm load corrections (K) at three instrument temperatures.**

**AMSU-A2 FM1 Channels:**

**AMSU-A1-2 PFM Channels: PFM**

| Instrument Temp. (C) | Ch 1 (K) | Ch 2 (K) | Instrument Temp. (C) | Ch 3 (K) | Ch 4 (K) | Ch 5 (K) | Ch 8 (K) |
|----------------------|----------|----------|----------------------|----------|----------|----------|----------|
| 30.52                | -0.067   | -0.103   | 38.14                | 0.105    | 0.041    | 0.025    | 0.009    |
| 11.49                | -0.038   | -0.121   | 17.98                | 0.147    | 0.073    | 0.046    | 0.030    |
| -7.59                | 0.017    | -0.144   | -1.78                | 0.136    | 0.065    | 0.017    | -0.023   |

**AMSU-A1-1 PFM Channels : PFM PLLO#1**

| Instrument Temp. (C) | Ch 6 (K) | Ch 7 (K) | Ch 9 (K) | Ch 10 (K) | Ch 11 (K) | Ch 12 (K) | Ch 13 (K) | Ch 14 (K) | Ch 15 (K) |
|----------------------|----------|----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 38.18                | 0.279    | 0.277    | 0.197    | 0.270     | 0.255     | 0.279     | 0.244     | 0.235     | 0.211     |
| 18.14                | 0.284    | 0.300    | 0.262    | 0.283     | 0.269     | 0.290     | 0.281     | 0.293     | 0.228     |
| -1.56                | 0.070    | 0.096    | 0.142    | 0.086     | 0.114     | 0.163     | 0.161     | 0.142     | 0.079     |

**AMSU-A1-1 Channels :**

**PFM PLLO#2**

| Instrument Temp. (C) | Ch 9 (K) | Ch 10 (K) | Ch 11 (K) | Ch 12 (K) | Ch 13 (K) | Ch 14 (K) |
|----------------------|----------|-----------|-----------|-----------|-----------|-----------|
| 38.32                | 0.173    | 0.165     | 0.172     | 0.155     | 0.175     | 0.138     |
| 18.10                | 0.257    | 0.237     | 0.242     | 0.251     | 0.258     | 0.284     |
| -1.49                | 0.109    | 0.090     | 0.110     | 0.172     | 0.132     | 0.176     |



### A.3 Correction to In-orbit Cold Space Calibration

For in-orbit cold space calibration, there is an uncertainty due to antenna side lobe interference with the Earth limb and spacecraft. The contribution from this uncertainty should be added to the cold space cosmic background temperature of 2.73K. Therefore, the “corrected” cold space temperature  $T_{cc}$  can be represented by

$$T_{cc} = 2.73 + \Delta T_c \quad (A-5)$$

where  $\Delta T_c$  represents the contribution due to antenna side lobe interference with the Earth limb and spacecraft. Aerojet made estimates of  $\Delta T_c$  for individual channels and its values [6, 7] are listed in Table A-4. These  $\Delta T_c$  values will be used initially and the final optimal values for  $\Delta T_c$  will be determined from the antenna pattern corrections [10] or post-launch calibration.

Table A-4. Values of  $\Delta T_c$  and limits of blackbody count variations.

| Channel | $\Delta T_c$ (K) | $\Delta C_w$ (count) |
|---------|------------------|----------------------|
| 1       | 1.73             | 18                   |
| 2       | 1.24             | 18                   |
| 3       | 1.23             | 18                   |
| 4       | 0.88             | 18                   |
| 5       | 1.87             | 18                   |
| 6       | 1.86             | 18                   |
| 7       | 1.76             | 18                   |
| 8       | 1.90             | 18                   |
| 9       | 1.83             | 18                   |
| 10      | 1.83             | 18                   |
| 11      | 1.83             | 24                   |
| 12      | 1.83             | 24                   |
| 13      | 1.83             | 30                   |
| 14      | 1.43             | 60                   |
| 15      | 1.09             | 21                   |



#### A.4 Limit of Blackbody Counts Variation

For each scan, the blackbody count  $C_w$  is the average of two samples. If the two samples of the blackbody differ by more than a pre-set limit of blackbody count variation  $\Delta C_w$ , the data in the scan will not be used. The  $\Delta C_w$  values for individual channels are listed in Table A-4. These  $\Delta C_w$  values, which equal approximately  $3\sigma$  (where  $\sigma$  is the standard deviation of the internal blackbody counts), are calculated from the TV calibration data.

#### A.5 Pre-launch Determined Weight Factors $w_k$ for the Internal Blackbody PRTs

The weight factors  $w_k$  (see Equation 2) assigned to individual PRTs in the internal blackbody targets are listed in Table A-5. All PRTs in NOAA-L AMSU-A are good.

Table A-5. Pre-launch determined weight factors  $w_i$  assigned to individual PRTs in blackbody targets.

| Antenna System | $w_1$ | $w_2$ | $w_3$ | $w_4$ | $w_5$ | $w_6$ | $w_7$ |
|----------------|-------|-------|-------|-------|-------|-------|-------|
| AMSU-A2        | 1     | 1     | 1     | 1     | 1     | 1     | 1     |
| AMSU-A1-1      | 1     | 1     | 1     | 1     | 1     |       |       |
| AMSU-A1-2      | 1     | 1     | 1     | 1     | 1     |       |       |

#### A.6 Conversion Coefficients of Analog Data

AMSU-A instrument has an analog telemetry bus to monitor key temperatures and voltages through the spacecraft. The resolutions of the analog telemetry received on the ground is 20 mV for one part in 255. To convert the analog data into physical quantities  $y$ , one must multiply the analog values by 0.02V (20mV) to obtain the measured output,  $x$ , in volts and then uses the conversion equation

$$y = B + Mx \quad (\text{A-6})$$

where the values of  $B$  and  $M$  are given in Tables A-6 and A-7 for NOAA-L AMSU-A2 and -A1, respectively.



**Table A-6. NOAA-L AMSU-A2 FM1 (S/N 103): Analog data conversion coefficients.**

| UIIS<br>Ref # | Description                           | Units<br>( of y) | m      | b       |
|---------------|---------------------------------------|------------------|--------|---------|
| 1             | Scanner Motor Temperature             | K                | 68.027 | 0       |
| 2             | Compensator Motor Temperature         | K                | 68.027 | 0       |
| 3             | RF Shelf Temperature                  | K                | 68.027 | 0       |
| 4             | Warm Load Temperature                 | K                | 68.027 | 0       |
| 5             | Compensator Motor Current (average)   | mA               | 45.850 | -5.500  |
| 6             | Antenna Drive Motor Current (average) | mA               | 44.330 | -21.270 |
| 7             | Signal Processing +15Vdc              | V                | 5.023  | 0       |
| 8             | Antenna Drive +15Vdc                  | V                | 4.918  | 0       |
| 9             | Signal Processing -15Vdc              | V                | -2.030 | -9.000  |
| 10            | Antenna Drive -15Vdc                  | V                | -1.958 | -9.000  |
| 11            | Receiver +8Vdc                        | V                | 1.834  | 0       |
| 12            | Signal Processing +5 Vdc              | V                | 1.675  | 0       |
| 13            | Antenna Drive +5Vdc                   | V                | 1.622  | 0       |
| 14            | Gunn Diode Osc. Voltage (channel 1)   | V                | 2.005  | 0       |
| 15            | Gunn Diode Osc. Voltage (channel 2)   | V                | 1.671  | 0       |

**Table A-7. NOAA-L AMSU-A1 PFM (S/N 102): Analog data conversion coefficients.**

| UIIS<br>Ref # | Description                                | Units<br>( of y) | m      | b       |
|---------------|--------------------------------------------|------------------|--------|---------|
| 1             | A1-1 Scanner Motor Temperature             | K                | 68.027 | 0       |
| 2             | A1-2 Scanner Motor Temperature             | K                | 68.027 | 0       |
| 3             | RF Shelf A1-1 Temperature                  | K                | 68.027 | 0       |
| 4             | RF Shelf A1-2 Temperature                  | K                | 68.027 | 0       |
| 5             | Warm Load A1-1 Temperature                 | K                | 68.027 | 0       |
| 6             | Warm Load A1-2 Temperature                 | K                | 68.027 | 0       |
| 7             | Antenna A1-1 Drive Motor Current (average) | mA               | 27.940 | -2.240  |
| 8             | Antenna A1-2 Drive Motor Current (average) | mA               | 26.380 | -18.070 |
| 9             | +15Vdc (Signal Processing)                 | V                | 5.050  | 0       |
| 10            | +15Vdc (Antenna Drive)                     | V                | 5.040  | 0       |
| 11            | -15Vdc (Signal Processing)                 | V                | -2.000 | -9.000  |
| 12            | -15Vdc (Antenna Drive)                     | V                | -1.980 | -9.000  |
| 13            | +8Vdc (Receiver )                          | V                | 1.830  | 0       |
| 14            | Signal Processing +5 Vdc                   | V                | 1.670  | 0       |
| 15            | Antenna Drive +5Vdc                        | V                | 1.660  | 0       |
| 16            | Phase Locked Loop (Ch. 9/14) +8.5VDC       | V                | 2.000  | 0       |
| 17            | Phase Locked Loop (Ch. 9/14) +15VDC        | V                | 5.010  | 0       |
| 18            | Phase Locked Loop (Ch. 9/14) -15VDC        | V                | -1.990 | -9.000  |
| 19            | Gunn Diode Osc. #4 (channel 3)             | V                | 1.790  | 0       |
| 20            | Gunn Diode Osc. #5 (channel 4)             | V                | 1.790  | 0       |
| 21            | Gunn Diode Osc. #6 (channel 5)             | V                | 1.790  | 0       |
| 22            | Gunn Diode Osc. #3 (channel 6)             | V                | 1.780  | 0       |
| 23            | Gunn Diode Osc. #2 (channel 7)             | V                | 1.780  | 0       |
| 24            | Gunn Diode Osc. #1 (channel 8)             | V                | 1.790  | 0       |
| 25            | PLLO#1 Lock Detect                         | V                | 7.400  | -14.800 |
| 26            | PLLO#2 Lock Detect                         | V                | 7.400  | -14.800 |
| 27            | Gunn Diode Osc. #7 (channel 15)            | V                | 1.650  | 0       |



## **APPENDIX B**

### **NOAA-M CPIDS : COEFFICIENTS OF AMSU-A1 S/N 104 (FM2) AND AMSU-A2 S/N 104 (FM2)**

In this appendix, the CPIDS for NOAA-M AMSU-A are presented in a similar fashion as those for NOAA-L AMSU-A given in the main text and Appendix A. Tables of coefficients and plots of results from analysis of the TV calibration data follow the same order as those of NOAA-L calibration data as closely as possible.



Table B-1. NOAA-M AMSU-A1 FM2 : Polynomial coefficients  
for converting PRT counts into temperatures.

| PRT<br>Number | Description     | fk0<br>(K) | fk1<br>(K/count) | fk2<br>(K/count^2) | fk3<br>(K/count^3) |
|---------------|-----------------|------------|------------------|--------------------|--------------------|
| 1             | Scan Motor A1-1 | 262.9264   | 1.782879E-03     | 4.651285E-09       | 3.016453E-15       |
| 2             | Scan Motor A1-2 | 262.9457   | 1.794984E-03     | 4.014630E-09       | 1.178214E-14       |
| 3             | Feedhorn A1-1   | 262.9824   | 1.787421E-03     | 4.479284E-09       | 4.003862E-15       |
| 4             | Feedhorn A1-2   | 262.9480   | 1.796941E-03     | 3.990959E-09       | 1.213830E-14       |
| 5             | RF Mux A1-1     | 262.9930   | 1.791427E-03     | 4.562482E-09       | 3.258688E-15       |
| 6             | RF Mux A1-2     | 262.9876   | 1.783315E-03     | 4.549435E-09       | 2.993637E-15       |
| 7             | L.O. CH 3       | 263.0508   | 1.796300E-03     | 4.093929E-09       | 1.079970E-14       |
| 8             | L.O. CH 4       | 262.9266   | 1.789260E-03     | 4.554566E-09       | 3.049904E-15       |
| 9             | L.O. CH 5       | 263.0612   | 1.798046E-03     | 3.986979E-09       | 1.268962E-14       |
| 10            | L.O. CH 6       | 263.2208   | 1.786634E-03     | 4.517242E-09       | 3.021994E-15       |
| 11            | L.O. CH 7       | 263.0943   | 1.710871E-03     | 1.525857E-08       | -2.792764E-13      |
| 12            | L.O. CH 8       | 263.1941   | 1.725553E-03     | 1.463346E-08       | -2.700232E-13      |
| 13            | L.O. CH 15      | 262.9590   | 1.787082E-03     | 4.553521E-09       | 2.961741E-15       |
| 14            | PLLO #2 CH 9-14 | 263.1783   | 1.716766E-03     | 1.514877E-08       | -2.787102E-13      |
| 15            | PLLO #1 CH 9-14 | 263.1875   | 1.722912E-03     | 1.469318E-08       | -2.706999E-13      |
| 16            | PLLO (Ref.Osc.) | 263.0786   | 1.786833E-03     | 4.551711E-09       | 2.707090E-15       |
| 17            | Mixer/IF CH 3   | 262.9888   | 1.796020E-03     | 3.998485E-09       | 1.186256E-14       |
| 18            | Mixer/IF CH 4   | 263.0844   | 1.784899E-03     | 4.506407E-09       | 3.640704E-15       |
| 19            | Mixer/IF CH 5   | 262.9594   | 1.797137E-03     | 3.954086E-09       | 1.269160E-14       |
| 20            | Mixer/IF CH 6   | 262.9237   | 1.785977E-03     | 4.526986E-09       | 3.482820E-15       |
| 21            | Mixer/IF CH 7   | 263.0457   | 1.797253E-03     | 3.976505E-09       | 1.255832E-14       |
| 22            | Mixer/IF CH 8   | 263.2087   | 1.788848E-03     | 4.534624E-09       | 2.771589E-15       |
| 23            | Mixer/IF CH9/14 | 263.0331   | 1.794866E-03     | 4.119775E-09       | 9.785078E-15       |
| 24            | Mixer/IF CH 15  | 263.1179   | 1.787349E-03     | 4.578916E-09       | 2.215207E-15       |
| 25            | IF Amp. CH11/14 | 263.2372   | 1.797438E-03     | 4.062329E-09       | 1.139440E-14       |
| 26            | IF Amp. CH 9    | 263.1272   | 1.785720E-03     | 4.583279E-09       | 2.127480E-15       |
| 27            | IF Amp. Ch. 10  | 262.9736   | 1.794427E-03     | 4.114111E-09       | 1.029068E-14       |
| 28            | IF Amp. Ch. 11  | 262.8804   | 1.782688E-03     | 4.604669E-09       | 1.871548E-15       |
| 29            | DC/DC Converter | 263.1144   | 1.789528E-03     | 4.503099E-09       | 4.160511E-15       |
| 30            | IF Amp. Ch. 13  | 262.9494   | 1.790211E-03     | 4.469882E-09       | 4.827499E-15       |
| 31            | IF Amp. Ch. 14  | 262.9767   | 1.798895E-03     | 3.948966E-09       | 1.244464E-14       |
| 32            | IF Amp. Ch. 12  | 263.0209   | 1.796938E-03     | 3.970665E-09       | 1.284796E-14       |
| 33            | RF Shelf A1-1   | 262.9493   | 1.795960E-03     | 4.021378E-09       | 1.165849E-14       |
| 34            | RF Shelf A1-2   | 263.2218   | 1.790430E-03     | 4.457330E-09       | 4.806016E-15       |
| 35            | Detector/PreAmp | 263.1320   | 1.786115E-03     | 4.444591E-09       | 5.163805E-15       |
| 36            | A1-1 WarmLoad#1 | 254.1414   | 1.689477E-03     | 6.344681E-09       | 3.193697E-14       |
| 37            | A1-1 WarmLoad#2 | 254.1487   | 1.691693E-03     | 6.341322E-09       | 3.225776E-14       |
| 38            | A1-1 WarmLoad#3 | 254.2609   | 1.688383E-03     | 6.366155E-09       | 3.285827E-14       |
| 39            | A1-1 WarmLoad#4 | 254.0264   | 1.691223E-03     | 6.366102E-09       | 3.158980E-14       |
| 40            | A1-1 WmLdCenter | 254.1180   | 1.687154E-03     | 6.324558E-09       | 3.341569E-14       |
| 41            | A1-2 WarmLoad#1 | 254.0312   | 1.689809E-03     | 6.276867E-09       | 3.309316E-14       |
| 42            | A1-2 WarmLoad#2 | 254.0746   | 1.689391E-03     | 6.330238E-09       | 3.196075E-14       |
| 43            | A1-2 WarmLoad#3 | 253.9810   | 1.688747E-03     | 6.415529E-09       | 3.026252E-14       |
| 44            | A1-2 WarmLoad#4 | 254.0501   | 1.691363E-03     | 6.261909E-09       | 3.320902E-14       |
| 45            | A1-2 WmLdCenter | 254.1199   | 1.690609E-03     | 6.336316E-09       | 3.169356E-14       |



Table B-2. NOAA-M AMSU-A2 FM2 : Polynomial coefficients  
for converting PRT counts into temperatures.

| PRT<br>Number | Description       | fk0<br>(K) | fk1<br>(K/count) | fk2<br>(K/count <sup>2</sup> ) | fk3<br>(K/count <sup>3</sup> ) |
|---------------|-------------------|------------|------------------|--------------------------------|--------------------------------|
| 1             | Scan Motor        | 262.8103   | 1.799263E-03     | 3.918056E-09                   | 1.378876E-14                   |
| 2             | Feedhorn          | 262.8875   | 1.798632E-03     | 3.861166E-09                   | 1.461288E-14                   |
| 3             | RF Mux            | 262.9754   | 1.787858E-03     | 4.418528E-09                   | 5.447643E-15                   |
| 4             | Mixer/IF CH 1     | 262.8911   | 1.797363E-03     | 3.951389E-09                   | 1.326321E-14                   |
| 5             | Mixer/IF CH 2     | 262.9980   | 1.786656E-03     | 4.536335E-09                   | 3.196675E-15                   |
| 6             | L.O. CH 1         | 263.0044   | 1.798525E-03     | 3.906646E-09                   | 1.384829E-14                   |
| 7             | L.O. CH 2         | 263.0494   | 1.787020E-03     | 4.515614E-09                   | 3.719867E-15                   |
| 8             | Compensator Motor | 263.0132   | 1.787472E-03     | 4.545698E-09                   | 2.838922E-15                   |
| 9             | Sub Reflector     | 263.0260   | 1.800103E-03     | 3.923436E-09                   | 1.371243E-14                   |
| 10            | DC/DC Converter   | 263.0176   | 1.788387E-03     | 4.490114E-09                   | 4.038087E-15                   |
| 11            | RF Shelf          | 262.9678   | 1.799042E-03     | 3.918873E-09                   | 1.347043E-14                   |
| 12            | Detector PreAmp   | 263.0857   | 1.786617E-03     | 4.625271E-09                   | 1.397384E-15                   |
| 13            | Warm Load Center  | 253.8701   | 1.692392E-03     | 6.261930E-09                   | 3.353704E-14                   |
| 14            | Warm Load #1      | 254.1862   | 1.692840E-03     | 6.363497E-09                   | 3.173994E-14                   |
| 15            | Warm Load #2      | 253.9909   | 1.691020E-03     | 6.407151E-09                   | 3.109133E-14                   |
| 16            | Warm Load #3      | 254.0674   | 1.690073E-03     | 6.403813E-09                   | 3.083828E-14                   |
| 17            | Warm Load #4      | 254.0519   | 1.691001E-03     | 6.339211E-09                   | 3.198690E-14                   |
| 18            | Warm Load #5      | 253.8955   | 1.690122E-03     | 6.397237E-09                   | 3.075373E-14                   |
| 19            | Warm Load #6      | 254.0301   | 1.691228E-03     | 6.453710E-09                   | 2.994629E-14                   |



**Table B-3. NOAA-M AMSU-A warm load corrections (K) at three instrument temperatures.**

**AMSU-A2 FM2 Channels:**

**AMSU-A1-2 FM2 Channels:**

| Instrument Temp. (C) | Ch 1  | Ch 2   | Instrument Temp. (C) | Ch 3   | Ch 4  | Ch 5  | Ch 8  |
|----------------------|-------|--------|----------------------|--------|-------|-------|-------|
| 30.40                | 0.060 | -0.009 | 38.45                | -0.016 | 0.073 | 0.058 | 0.040 |
| 11.86                | 0.006 | -0.072 | 18.35                | 0.184  | 0.067 | 0.087 | 0.057 |
| -7.38                | 0.020 | -0.044 | -2.79                | -0.040 | 0.011 | 0.038 | 0.000 |

**AMSU-A1-1 Channels :**

**FM2 PLLO#1**

| Instrument Temp. (C) | Ch 6  | Ch 7  | Ch 9  | Ch 10 | Ch 11 | Ch 12 | Ch 13 | Ch 14 | Ch 15 |
|----------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 38.58                | 0.158 | 0.153 | 0.148 | 0.166 | 0.147 | 0.126 | 0.108 | 0.145 | 0.104 |
| 18.81                | 0.096 | 0.131 | 0.108 | 0.139 | 0.139 | 0.096 | 0.129 | 0.130 | 0.067 |
| -1.59                | 0.048 | 0.125 | 0.120 | 0.101 | 0.077 | 0.092 | 0.083 | 0.103 | 0.067 |

**AMSU-A1-1 Channels :**

**FM2 PLLO#2**

| Instrument Temp. (C) | Ch 9  | Ch 10 | Ch 11 | Ch 12 | Ch 13 | Ch 14 |
|----------------------|-------|-------|-------|-------|-------|-------|
| 38.40                | 0.180 | 0.194 | 0.173 | 0.169 | 0.077 | 0.148 |
| 18.67                | 0.045 | 0.099 | 0.092 | 0.050 | 0.077 | 0.047 |
| -1.49                | 0.077 | 0.066 | 0.098 | 0.068 | 0.016 | 0.062 |



**Table B-4. NOAA-M best-fit values of the nonlinearity parameter  $u$  in dimension of  $(m^2-sr-cm^{-1})/mW$ .**

| AMSU-A2 FM2 Channels: |          |          | AMSU-A1-2 FM2 Channels: |           |           |           |           |
|-----------------------|----------|----------|-------------------------|-----------|-----------|-----------|-----------|
| Instrument Temp. (C)  | Ch 1     | Ch 2     | Instrument Temp. (C)    | Ch 3      | Ch 4      | Ch 5      | Ch 8      |
| 30.39                 | 1.210115 | 0.264214 | 38.24                   | -0.035936 | 0.009401  | -0.465294 | -0.021454 |
| 11.81                 | 0.866221 | 0.505818 | 18.22                   | -0.066013 | -0.001872 | -0.550842 | -0.050808 |
| -7.58                 | 0.934877 | 0.142476 | -2.61                   | 0.030000  | 0.018307  | -0.615999 | -0.000209 |

| AMSU-A1-1 Channels : |           |          | FM2 PLL0#1 |           |          |          |           |          |          |  |  |  |  |  |
|----------------------|-----------|----------|------------|-----------|----------|----------|-----------|----------|----------|--|--|--|--|--|
| Instrument Temp. (C) | Ch 6      | Ch 7     | Ch 9       | Ch 10     | Ch 11    | Ch 12    | Ch 13     | Ch 14    | Ch 15    |  |  |  |  |  |
| 38.21                | 0.049959  | 0.425206 | 0.234889   | 0.081573  | 0.752180 | 0.548523 | 0.068187  | 0.039951 | 0.157433 |  |  |  |  |  |
| 18.68                | -0.059291 | 0.163680 | 0.263860   | -0.047256 | 0.580593 | 0.399720 | -0.042743 | 0.077007 | 0.159881 |  |  |  |  |  |
| -1.50                | -0.151499 | 0.244209 | 0.449420   | -0.003298 | 0.672451 | 0.458582 | -0.218273 | 0.020141 | 0.173077 |  |  |  |  |  |

| AMSU-A1-1 Channels : |          |           | FM2 PLL0#2 |          |           |           |  |  |  |  |  |  |  |
|----------------------|----------|-----------|------------|----------|-----------|-----------|--|--|--|--|--|--|--|
| Instrument Temp. (C) | Ch 9     | Ch 10     | Ch 11      | Ch 12    | Ch 13     | Ch 14     |  |  |  |  |  |  |  |
| 38.3                 | 0.529974 | 0.033513  | 0.878340   | 0.700747 | 0.022907  | 0.253735  |  |  |  |  |  |  |  |
| 18.7                 | 0.363512 | -0.036238 | 0.717733   | 0.426826 | -0.085231 | 0.010259  |  |  |  |  |  |  |  |
| -1.5                 | 0.274684 | -0.326168 | 0.529516   | 0.292638 | -0.315390 | -0.003509 |  |  |  |  |  |  |  |



**Table B-5. NOAA-M AMSU-A : Radiometric counts at zero radiances.**

| AMSU-A2 FM2 Channels: |                 |       |       | AMSU-A1-2 FM2 Channels: |                 |       |       |       |       |
|-----------------------|-----------------|-------|-------|-------------------------|-----------------|-------|-------|-------|-------|
| Instrument Temp. (C)  | Scene Temp. (K) | Ch 1  | Ch 2  | Instrument Temp. (C)    | Scene Temp. (K) | Ch 3  | Ch 4  | Ch 5  | Ch 8  |
| 30.28                 | 83.99           | 12019 | 11547 | 38.03                   | 83.92           | 12256 | 12664 | 11678 | 12542 |
| 30.35                 | 129.84          | 12019 | 11547 | 38.21                   | 129.74          | 12261 | 12664 | 11675 | 12539 |
| 30.33                 | 179.79          | 12015 | 11548 | 38.28                   | 179.60          | 12254 | 12663 | 11672 | 12534 |
| 30.33                 | 229.89          | 12007 | 11544 | 38.16                   | 229.68          | 12258 | 12666 | 11674 | 12535 |
| 30.47                 | 280.00          | 12010 | 11553 | 38.37                   | 279.83          | 12259 | 12666 | 11670 | 12530 |
| 30.61                 | 329.87          | 12004 | 11551 | 38.40                   | 329.88          | 12248 | 12666 | 11666 | 12526 |
|                       |                 |       |       |                         |                 |       |       |       |       |
| 11.74                 | 83.96           | 11790 | 11631 | 18.25                   | 83.88           | 12878 | 13036 | 12115 | 12896 |
| 11.82                 | 129.84          | 11786 | 11627 | 18.27                   | 129.54          | 12873 | 13038 | 12113 | 12895 |
| 11.85                 | 179.85          | 11786 | 11626 | 18.25                   | 179.65          | 12872 | 13044 | 12113 | 12895 |
| 11.82                 | 229.79          | 11785 | 11625 | 18.12                   | 229.83          | 12881 | 13044 | 12112 | 12896 |
| 11.80                 | 279.77          | 11786 | 11625 | 18.33                   | 279.74          | 12866 | 13040 | 12107 | 12892 |
| 11.85                 | 329.91          | 11786 | 11623 | 18.10                   | 329.93          | 12866 | 13044 | 12105 | 12892 |
|                       |                 |       |       |                         |                 |       |       |       |       |
| -7.79                 | 83.98           | 11644 | 11554 | -2.43                   | 83.97           | 13601 | 13214 | 12151 | 12936 |
| -7.77                 | 129.89          | 11644 | 11554 | -2.46                   | 129.85          | 13604 | 13209 | 12149 | 12936 |
| -7.66                 | 179.93          | 11646 | 11555 | -2.39                   | 179.67          | 13601 | 13208 | 12147 | 12936 |
| -7.46                 | 229.75          | 11648 | 11556 | -2.49                   | 229.40          | 13598 | 13210 | 12144 | 12938 |
| -7.69                 | 279.64          | 11649 | 11555 | -2.97                   | 279.73          | 13611 | 13217 | 12142 | 12942 |
| -7.09                 | 329.76          | 11651 | 11556 | -2.93                   | 329.95          | 13611 | 13221 | 12136 | 12945 |

| AMSU-A1-1 Channels : |                 | FM2 PLL0#1 |       |       |       |       |       |       |       |       |
|----------------------|-----------------|------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Instrument Temp. (C) | Scene Temp. (K) | Ch 6       | Ch 7  | Ch 9  | Ch 10 | Ch 11 | Ch 12 | Ch 13 | Ch 14 | Ch 15 |
| 38.08                | 83.97           | 12424      | 13909 | 13121 | 13088 | 16557 | 13137 | 12173 | 13369 | 12728 |
| 37.85                | 129.78          | 12429      | 13909 | 13126 | 13094 | 16599 | 13168 | 12192 | 13438 | 12738 |
| 38.06                | 179.67          | 12424      | 13907 | 13119 | 13089 | 16585 | 13153 | 12183 | 13432 | 12730 |
| 38.23                | 229.70          | 12421      | 13908 | 13115 | 13088 | 16573 | 13140 | 12178 | 13425 | 12726 |
| 38.43                | 279.81          | 12419      | 13909 | 13109 | 13088 | 16583 | 13136 | 12179 | 13443 | 12722 |
| 38.60                | 329.95          | 12414      | 13909 | 13111 | 13088 | 16580 | 13122 | 12174 | 13446 | 12717 |
|                      |                 |            |       |       |       |       |       |       |       |       |
| 18.65                | 83.92           | 12793      | 14144 | 13765 | 13466 | 17528 | 14210 | 12512 | 14086 | 13322 |
| 18.76                | 129.63          | 12795      | 14146 | 13761 | 13465 | 17541 | 14215 | 12523 | 14102 | 13321 |
| 18.63                | 179.69          | 12799      | 14147 | 13763 | 13467 | 17573 | 14232 | 12542 | 14134 | 13326 |
| 18.50                | 229.76          | 12799      | 14148 | 13766 | 13470 | 17597 | 14244 | 12557 | 14158 | 13330 |
| 18.80                | 279.77          | 12793      | 14147 | 13754 | 13463 | 17593 | 14228 | 12557 | 14160 | 13323 |
| 18.71                | 329.97          | 12791      | 14153 | 13756 | 13469 | 17641 | 14246 | 12586 | 14205 | 13334 |
|                      |                 |            |       |       |       |       |       |       |       |       |
| -1.56                | 84.01           | 12897      | 13853 | 14354 | 13830 | 18733 | 15252 | 13170 | 14925 | 13845 |
| -1.80                | 129.80          | 12890      | 13842 | 14360 | 13828 | 18746 | 15271 | 13178 | 14969 | 13846 |
| -1.67                | 179.95          | 12887      | 13845 | 14360 | 13832 | 18751 | 15272 | 13183 | 14988 | 13844 |
| -1.55                | 229.74          | 12886      | 13849 | 14354 | 13831 | 18751 | 15265 | 13178 | 15002 | 13844 |
| -1.50                | 279.79          | 12887      | 13857 | 14348 | 13834 | 18769 | 15272 | 13182 | 15056 | 13851 |
| -0.95                | 330.05          | 12886      | 13872 | 14331 | 13835 | 18767 | 15251 | 13188 | 15062 | 13846 |



**Table B-6. NOAA-M AMSU-A: Channel gains (count/K) at three instrument temperatures.**

| AMSU-A2 FM2 Channels: |                 |       |       | AMSU-A1-2 FM2 Channels: |                 |                |                |                |                |
|-----------------------|-----------------|-------|-------|-------------------------|-----------------|----------------|----------------|----------------|----------------|
| Instrument Temp. (C)  | Scene Temp. (K) | Ch 1  | Ch 2  | Instrument Temp. (C)    | Scene Temp. (K) | Ch 3 (Count/K) | Ch 4 (Count/K) | Ch 5 (Count/K) | Ch 8 (Count/K) |
| 30.28                 | 83.99           | 15.23 | 13.41 | 38.03                   | 83.92           | 12.36          | 13.39          | 14.76          | 14.96          |
| 30.35                 | 129.84          | 15.23 | 13.41 | 38.21                   | 129.74          | 12.35          | 13.38          | 14.75          | 14.94          |
| 30.33                 | 179.79          | 15.23 | 13.42 | 38.28                   | 179.60          | 12.35          | 13.38          | 14.75          | 14.94          |
| 30.33                 | 229.89          | 15.24 | 13.43 | 38.16                   | 229.68          | 12.36          | 13.40          | 14.77          | 14.95          |
| 30.47                 | 280.00          | 15.23 | 13.43 | 38.37                   | 279.83          | 12.36          | 13.39          | 14.77          | 14.95          |
| 30.61                 | 329.87          | 15.22 | 13.44 | 38.40                   | 329.88          | 12.36          | 13.40          | 14.78          | 14.95          |
|                       |                 |       |       |                         |                 |                |                |                |                |
| 11.74                 | 83.96           | 17.07 | 14.57 | 18.25                   | 83.88           | 14.21          | 14.57          | 16.04          | 16.29          |
| 11.82                 | 129.84          | 17.07 | 14.57 | 18.27                   | 129.54          | 14.22          | 14.57          | 16.04          | 16.30          |
| 11.85                 | 179.85          | 17.06 | 14.57 | 18.25                   | 179.65          | 14.22          | 14.58          | 16.05          | 16.30          |
| 11.82                 | 229.79          | 17.06 | 14.57 | 18.12                   | 229.83          | 14.23          | 14.59          | 16.06          | 16.31          |
| 11.80                 | 279.77          | 17.05 | 14.56 | 18.33                   | 279.74          | 14.22          | 14.58          | 16.06          | 16.31          |
| 11.85                 | 329.91          | 17.03 | 14.55 | 18.10                   | 329.93          | 14.24          | 14.61          | 16.09          | 16.34          |
|                       |                 |       |       |                         |                 |                |                |                |                |
| -7.79                 | 83.98           | 18.38 | 15.21 | -2.43                   | 83.97           | 14.64          | 15.55          | 17.08          | 17.15          |
| -7.77                 | 129.89          | 18.38 | 15.22 | -2.46                   | 129.85          | 14.63          | 15.54          | 17.07          | 17.14          |
| -7.66                 | 179.93          | 18.37 | 15.21 | -2.39                   | 179.67          | 14.63          | 15.54          | 17.07          | 17.14          |
| -7.46                 | 229.75          | 18.36 | 15.20 | -2.49                   | 229.40          | 14.64          | 15.55          | 17.08          | 17.15          |
| -7.69                 | 279.64          | 18.38 | 15.20 | -2.97                   | 279.73          | 14.69          | 15.60          | 17.12          | 17.20          |
| -7.09                 | 329.76          | 18.33 | 15.18 | -2.93                   | 329.95          | 14.70          | 15.62          | 17.14          | 17.24          |

| AMSU-A1-1 Channels : |                 | FM2 PLL0#1 |       |       |       |       |       |       |       |       |
|----------------------|-----------------|------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Instrument Temp. (C) | Scene Temp. (K) | Ch 6       | Ch 7  | Ch 9  | Ch 10 | Ch 11 | Ch 12 | Ch 13 | Ch 14 | Ch 15 |
| 38.08                | 83.97           | 13.00      | 12.49 | 14.02 | 14.68 | 19.11 | 12.24 | 10.17 | 14.45 | 6.37  |
| 37.85                | 129.78          | 13.02      | 12.51 | 14.05 | 14.73 | 19.23 | 12.33 | 10.23 | 14.64 | 6.39  |
| 38.06                | 179.67          | 13.01      | 12.50 | 14.02 | 14.70 | 19.18 | 12.29 | 10.20 | 14.60 | 6.38  |
| 38.23                | 229.70          | 13.00      | 12.49 | 14.00 | 14.67 | 19.13 | 12.24 | 10.17 | 14.57 | 6.36  |
| 38.43                | 279.81          | 12.99      | 12.48 | 13.98 | 14.65 | 19.13 | 12.22 | 10.16 | 14.60 | 6.35  |
| 38.60                | 329.95          | 12.98      | 12.46 | 13.96 | 14.62 | 19.09 | 12.17 | 10.14 | 14.59 | 6.34  |
|                      |                 |            |       |       |       |       |       |       |       |       |
| 18.65                | 83.92           | 14.11      | 13.27 | 15.54 | 16.58 | 22.58 | 15.58 | 11.77 | 17.25 | 7.68  |
| 18.76                | 129.63          | 14.11      | 13.27 | 15.53 | 16.58 | 22.61 | 15.59 | 11.78 | 17.29 | 7.67  |
| 18.63                | 179.69          | 14.12      | 13.27 | 15.54 | 16.59 | 22.69 | 15.63 | 11.83 | 17.37 | 7.68  |
| 18.50                | 229.76          | 14.14      | 13.28 | 15.54 | 16.60 | 22.74 | 15.66 | 11.87 | 17.43 | 7.69  |
| 18.80                | 279.77          | 14.12      | 13.27 | 15.51 | 16.56 | 22.69 | 15.60 | 11.85 | 17.40 | 7.67  |
| 18.71                | 329.97          | 14.12      | 13.27 | 15.51 | 16.57 | 22.78 | 15.62 | 11.91 | 17.49 | 7.68  |
|                      |                 |            |       |       |       |       |       |       |       |       |
| -1.56                | 84.01           | 15.13      | 14.12 | 16.85 | 18.59 | 27.02 | 19.29 | 14.34 | 20.68 | 8.84  |
| -1.80                | 129.80          | 15.12      | 14.12 | 16.87 | 18.62 | 27.10 | 19.38 | 14.39 | 20.83 | 8.85  |
| -1.67                | 179.95          | 15.12      | 14.12 | 16.86 | 18.60 | 27.09 | 19.36 | 14.39 | 20.85 | 8.84  |
| -1.55                | 229.74          | 15.11      | 14.12 | 16.85 | 18.59 | 27.07 | 19.33 | 14.37 | 20.88 | 8.84  |
| -1.50                | 279.79          | 15.11      | 14.13 | 16.85 | 18.58 | 27.09 | 19.34 | 14.37 | 21.01 | 8.84  |
| -0.95                | 330.05          | 15.08      | 14.13 | 16.82 | 18.52 | 27.00 | 19.23 | 14.35 | 20.97 | 8.82  |



**Table B-7. NOAA-M AMSU-A2 FM2 (S/N 104) : Analog data conversion coefficients**

| UIIS<br>Ref # | Description                           | Units<br>( of y) | m      | b       |
|---------------|---------------------------------------|------------------|--------|---------|
| 1             | Scanner Motor Temperature             | K                | 68.027 | 0       |
| 2             | Compensator Motor Temperature         | K                | 68.027 | 0       |
| 3             | RF Shelf Temperature                  | K                | 68.027 | 0       |
| 4             | Warm Load Temperature                 | K                | 68.027 | 0       |
| 5             | Compensator Motor Current (average)   | mA               | 45.850 | -5.500  |
| 6             | Antenna Drive Motor Current (average) | mA               | 44.330 | -21.270 |
| 7             | Signal Processing +15Vdc              | V                | 5.020  | 0       |
| 8             | Antenna Drive +15Vdc                  | V                | 4.897  | 0       |
| 9             | Signal Processing -15Vdc              | V                | -1.714 | -9.000  |
| 10            | Antenna Drive -15Vdc                  | V                | -1.600 | -9.000  |
| 11            | Receiver +8Vdc                        | V                | 1.836  | 0       |
| 12            | Signal Processing +5 Vdc              | V                | 1.674  | 0       |
| 13            | Antenna Drive +5Vdc                   | V                | 1.651  | 0       |
| 14            | Gunn Diode Osc. Voltage (channel 1)   | V                | 2.000  | 0       |
| 15            | Gunn Diode Osc. Voltage (channel 2)   | V                | 1.667  | 0       |

**Table B-8. NOAA-M AMSU-A1 FM2 (S/N 104): Analog data conversion coefficients.**

| UIIS<br>Ref # | Description                                | Units<br>( of y) | m      | b       |
|---------------|--------------------------------------------|------------------|--------|---------|
| 1             | A1-1 Scanner Motor Temperature             | K                | 68.027 | 0       |
| 2             | A1-2 Scanner Motor Temperature             | K                | 68.027 | 0       |
| 3             | RF Shelf A1-1 Temperature                  | K                | 68.027 | 0       |
| 4             | RF Shelf A1-2 Temperature                  | K                | 68.027 | 0       |
| 5             | Warm Load A1-1 Temperature                 | K                | 68.027 | 0       |
| 6             | Warm Load A1-2 Temperature                 | K                | 68.027 | 0       |
| 7             | Antenna A1-1 Drive Motor Current (average) | mA               | 27.830 | -2.780  |
| 8             | Antenna A1-2 Drive Motor Current (average) | mA               | 27.700 | -13.030 |
| 9             | +15Vdc (Signal Processing)                 | V                | 4.980  | 0       |
| 10            | +15Vdc (Antenna Drive)                     | V                | 5.000  | 0       |
| 11            | -15Vdc (Signal Processing)                 | V                | -2.020 | -9.000  |
| 12            | -15Vdc (Antenna Drive)                     | V                | -2.010 | -9.000  |
| 13            | +8Vdc (Receiver )                          | V                | 1.830  | 0       |
| 14            | Signal Processing +5 Vdc                   | V                | 1.670  | 0       |
| 15            | Antenna Drive +5Vdc                        | V                | 1.660  | 0       |
| 16            | Phase Locked Loop (Ch. 9/14) +8.5VDC       | V                | 2.000  | 0       |
| 17            | Phase Locked Loop (Ch. 9/14) +15VDC        | V                | 5.000  | 0       |
| 18            | Phase Locked Loop (Ch. 9/14) -15VDC        | V                | -2.020 | -9.000  |
| 19            | Gunn Diode Osc. #4 (channel 3)             | V                | 1.770  | 0       |
| 20            | Gunn Diode Osc. #5 (channel 4)             | V                | 1.790  | 0       |
| 21            | Gunn Diode Osc. #6 (channel 5)             | V                | 1.780  | 0       |
| 22            | Gunn Diode Osc. #3 (channel 6)             | V                | 1.780  | 0       |
| 23            | Gunn Diode Osc. #2 (channel 7)             | V                | 1.770  | 0       |
| 24            | Gunn Diode Osc. #1 (channel 8)             | V                | 1.770  | 0       |
| 25            | PLLO#1 Lock Detect                         | V                | 7.400  | -14.800 |
| 26            | PLLO#2 Lock Detect                         | V                | 7.400  | -14.800 |
| 27            | Gunn Diode Osc. #7 (channel 15)            | V                | 1.650  | 0       |



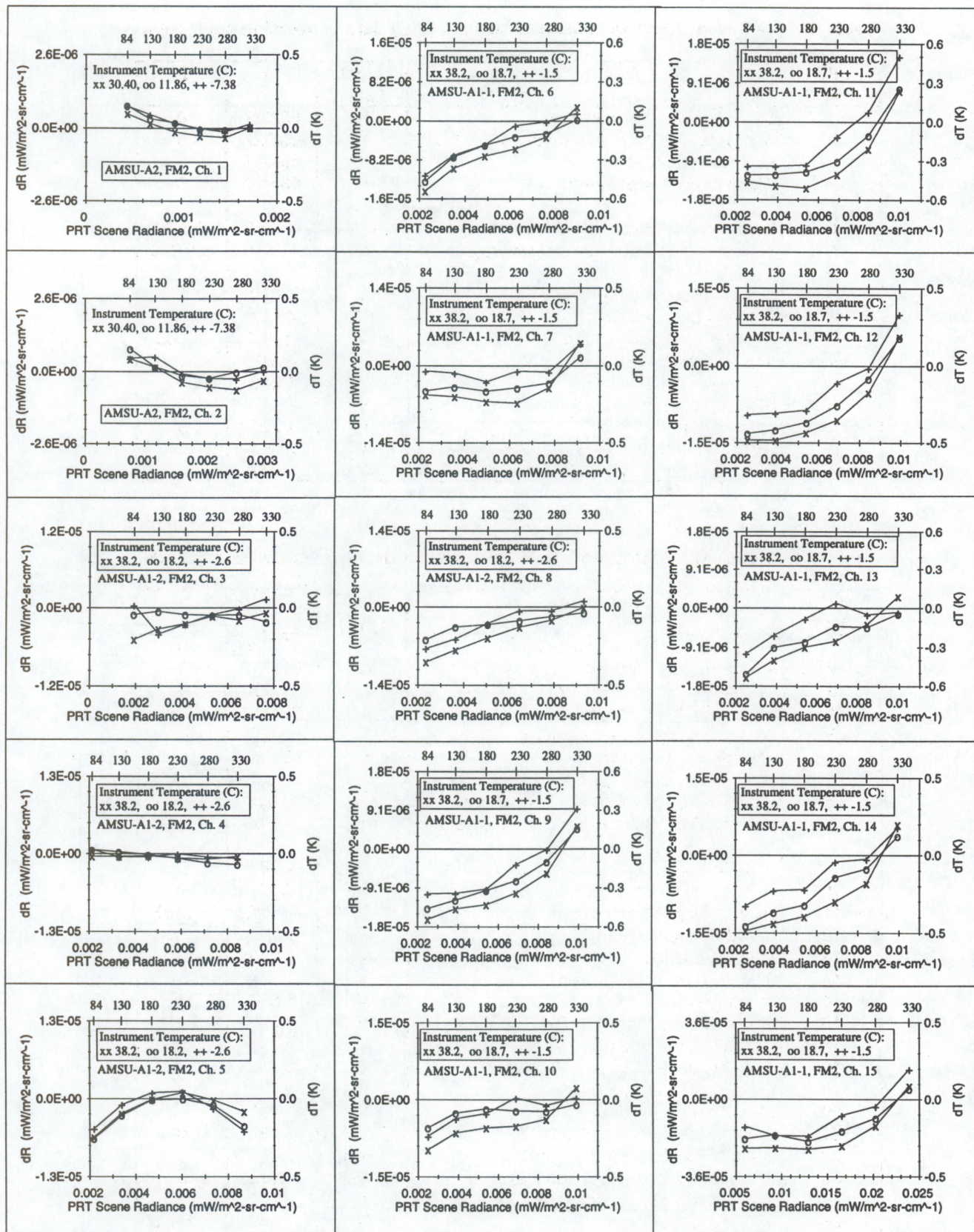


Figure B-1. NOAA-M AMSU-A : Calibration accuracies at three instrument temperatures.



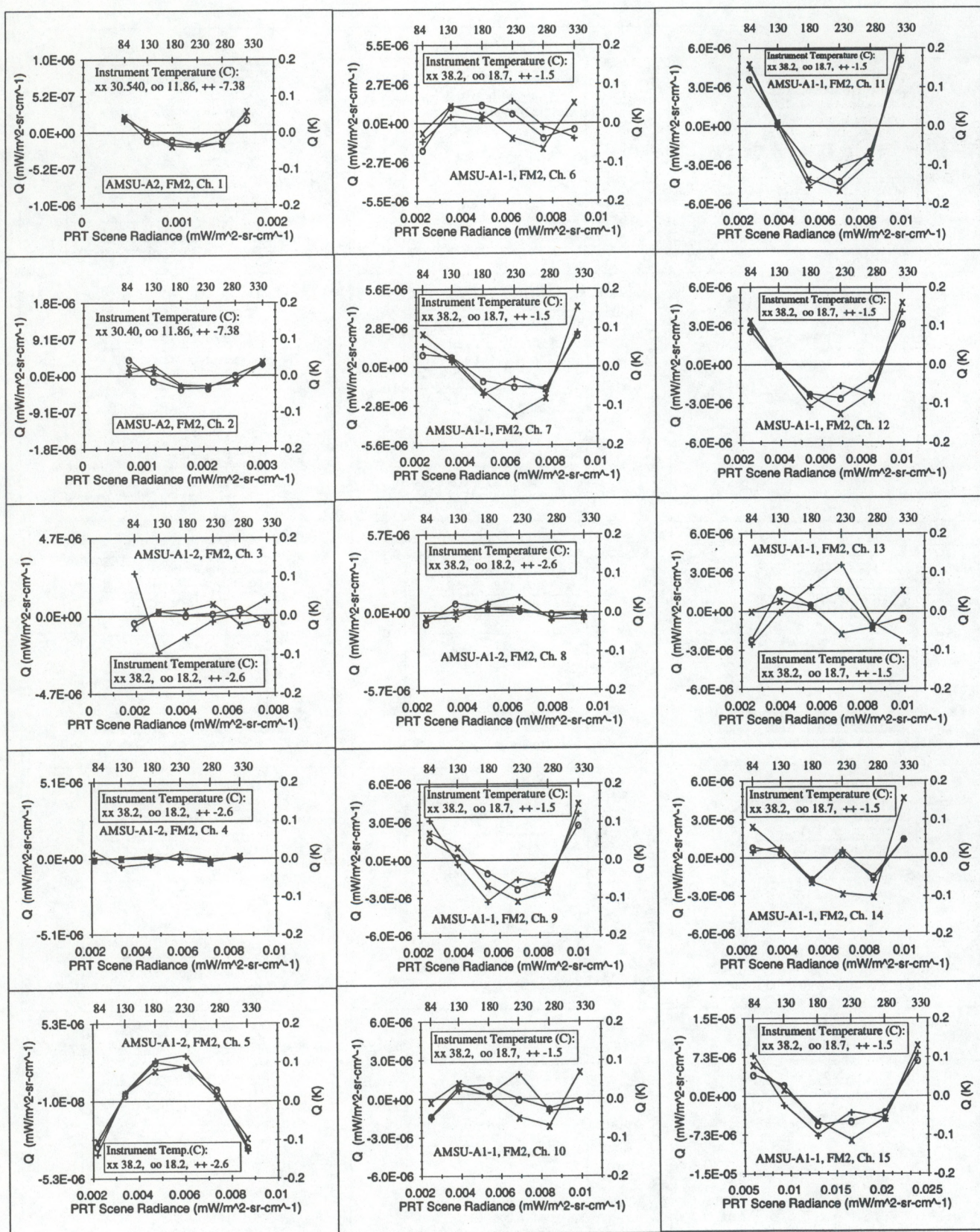


Figure B-2. NOAA-M AMSU-A : Residuals after least-squares fit of the PRT scene radiances as a function of RsL as defined in Equation (7).



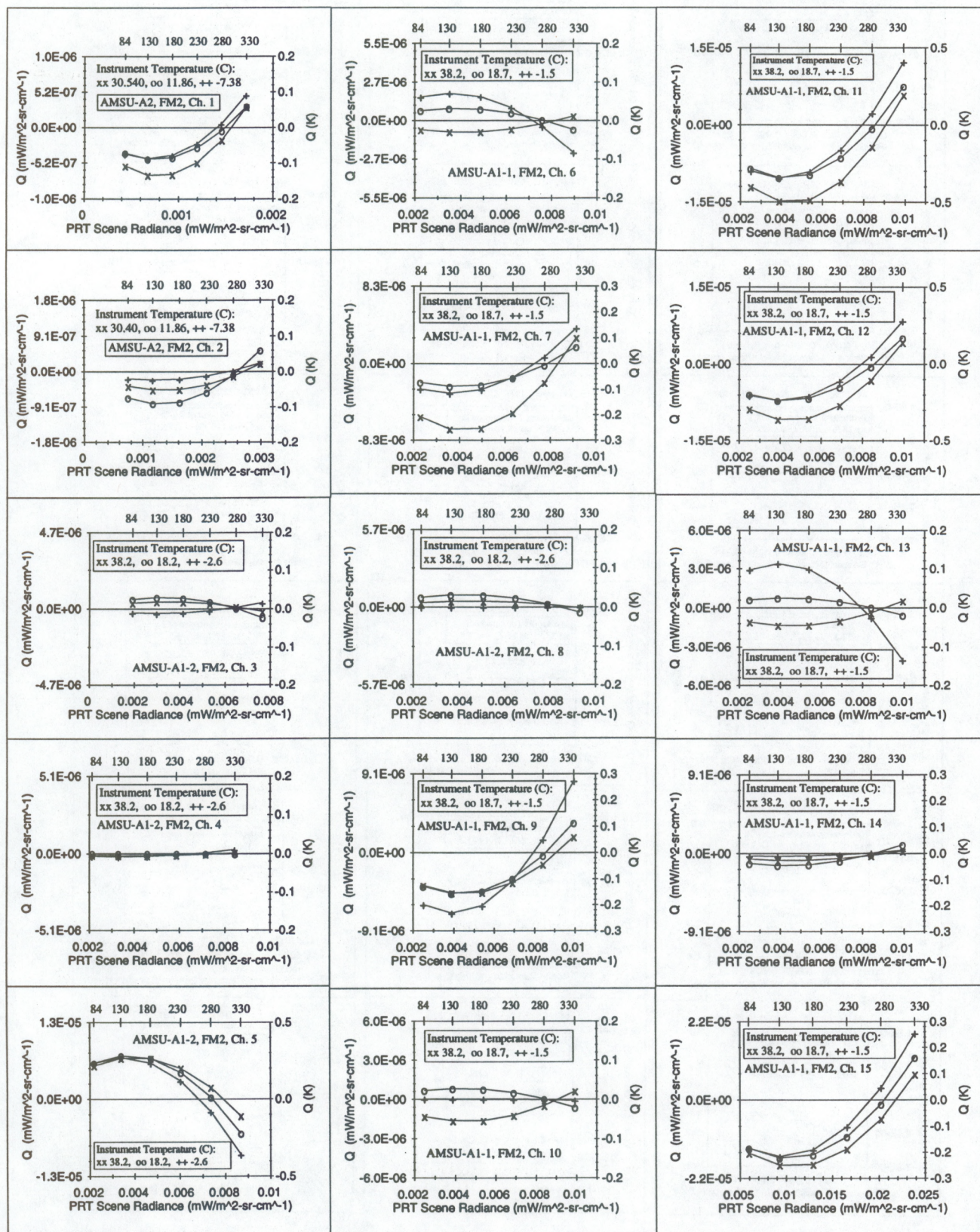


Figure B-3. NOAA-M AMSU-A : Simulated nonlinear corrections as expected from in-orbit data.



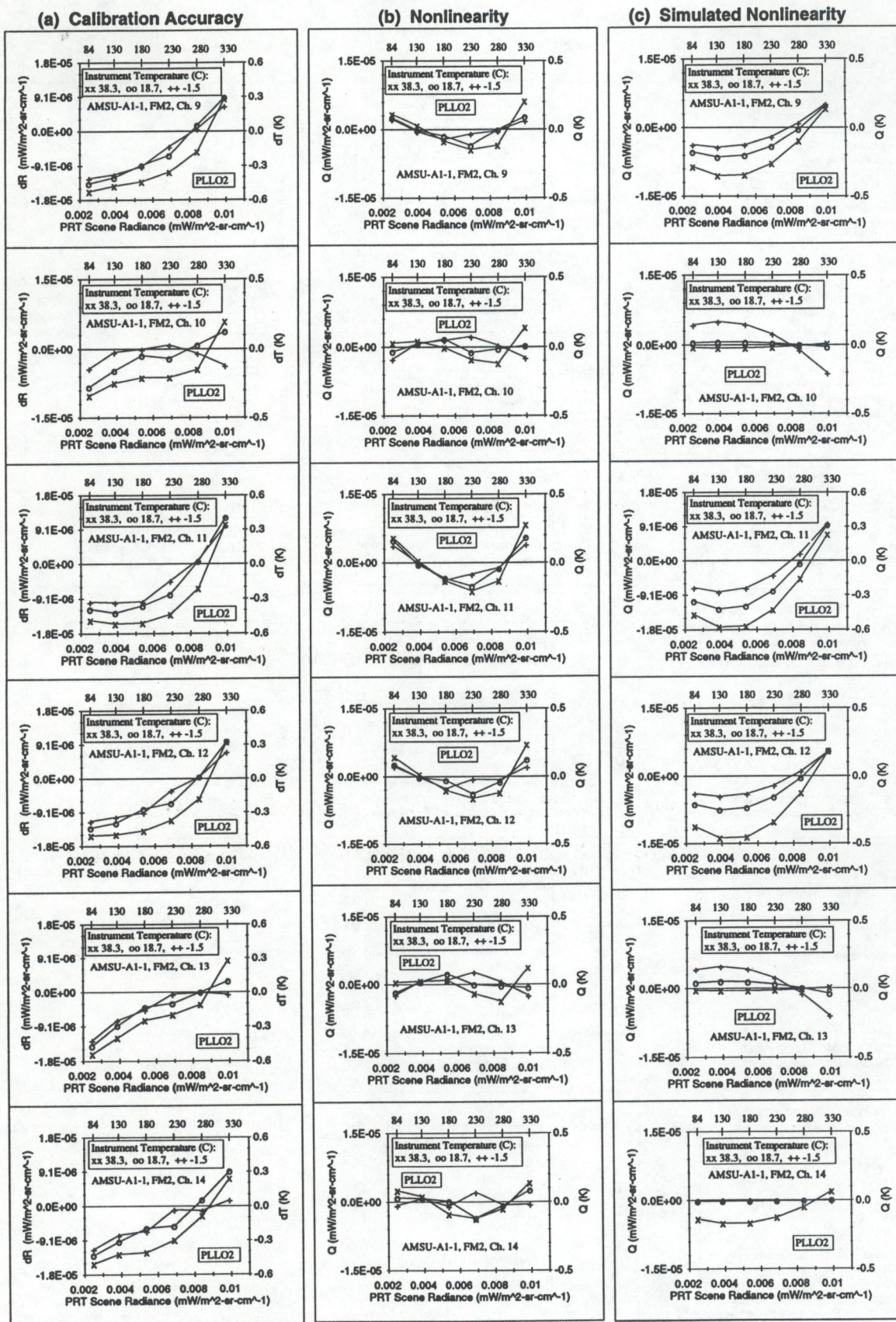


Figure B-4. NOAA-M AMSU-A : Calibration results with PLL02 in Channels 9-14,  
(a) calibration accuracy, (b) measured nonlinearity, and (c) simulated nonlinearity.



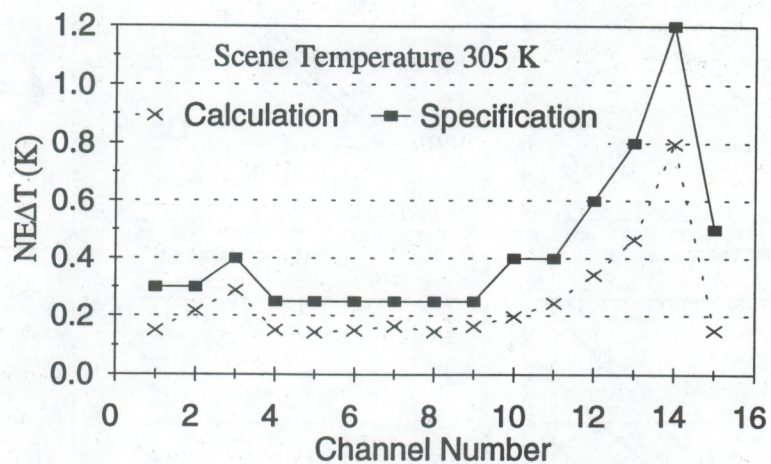


Figure B-5. NOAA-M AMSU-A : Comparison of the measured NEdT values with specification.



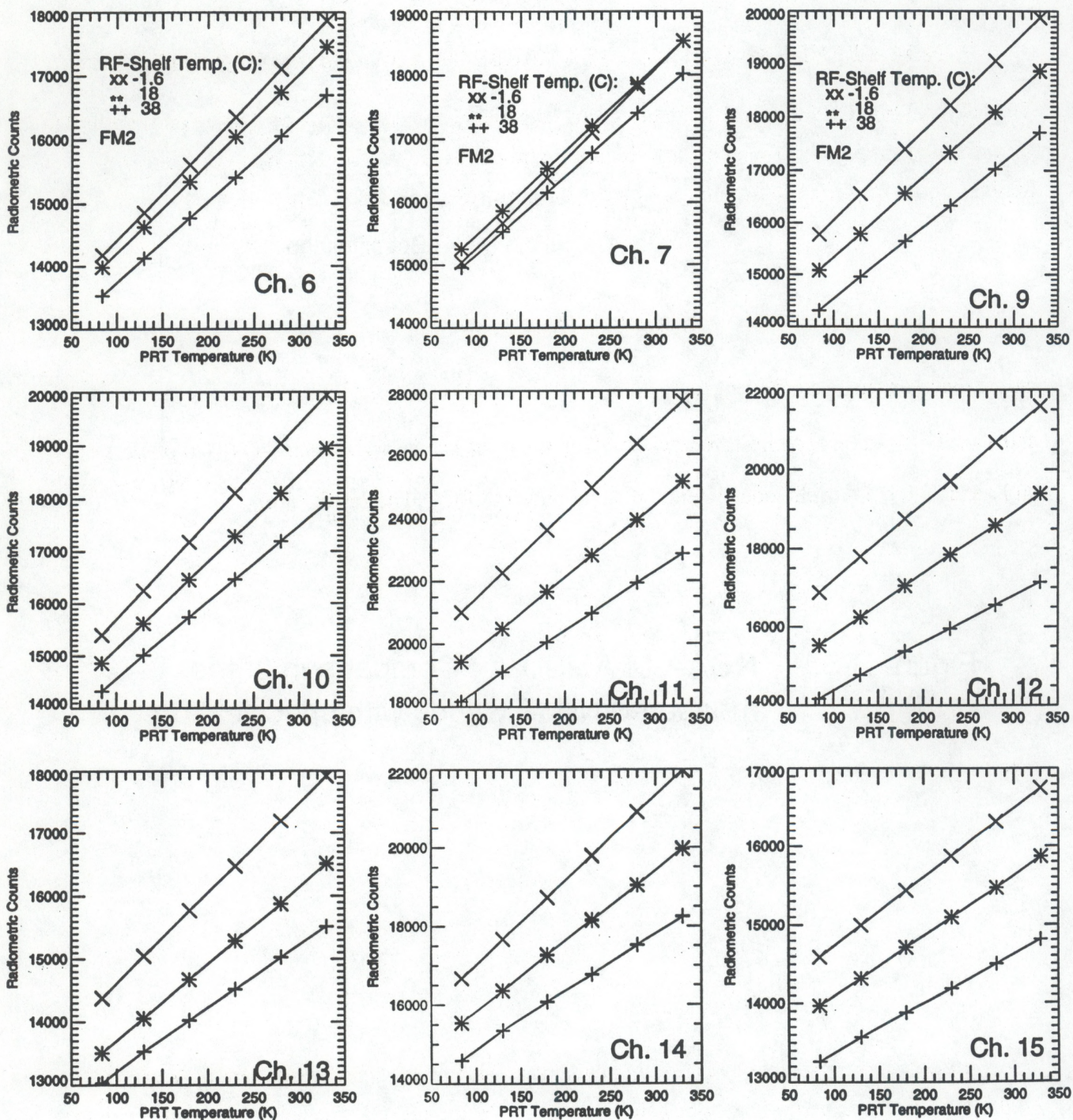


Figure B-6. NOAA-M AMSU-A : Radiometric counts at three instrument temperatures versus PRT temperatures. All channels are from AMSU-A1-1 FM2.



## APPENDIX C

### NOAA LEVEL 1B DATA AND SAMPLES OF NOAA-15 AMSU-A DATA

The NOAA Polar Orbiter Level 1B data are raw data that have been quality controlled and assembled into discrete data sets, to which Earth location and calibration information are appended but not applied. For simplification of application, one can rewrite Equation (4) as,

$$R_s = a_0 + a_1 C_s + a_2 C_s^2 \quad \frac{mW}{m^2-sr-cm^{-1}} \quad (C-1)$$

where the calibration coefficients  $a_i$  ( where  $i = 0, 1$ , and  $2$ ) can be expressed in terms of  $R_w$ ,  $G$ ,  $\overline{C_w}$  and  $\overline{C_c}$ . This can be accomplished by rewriting the right-hand side of Equation (4) in powers of  $C_s$  and equates the  $a_i$ 's to the coefficients of same powers of  $C_s$ . The results are,

$$a_0 = R_w - \frac{\overline{C_w}}{G} + u \frac{\overline{C_w} \overline{C_c}}{G^2} , \quad \frac{mW}{m^2-sr-cm^{-1}} \quad (C-2)$$

$$a_1 = \frac{1}{G} - u \frac{\overline{C_c} + \overline{C_w}}{G^2} , \quad \frac{mW}{(m^2-sr-cm^{-1}) count} \quad (C-3)$$

and

$$a_2 = u_2 \frac{1}{G^2} , \quad \frac{mW}{(m^2-sr-cm^{-1}) count^2} \quad (C-4)$$

These calibration coefficients will be calculated for scan line at each channel and appended to the 1B data. With these coefficients, one can simply apply Equation (C-1) to obtain the scene radiance  $R_s$ . Users, who prefer brightness temperature instead of radiance, can make the simple conversion,

$$T_s = B^{-1}(R_s) \quad (C-5)$$



where  $B^{-1}(R_s)$  is the inverse of the Planck function for a radiance  $R_s$ . The  $T_s$  is the antenna temperature (or radiometric temperature) which can be converted into brightness temperature by applying an antenna pattern correction [10].

The coefficients defined in Equations (C-2) to (C-4) are functions of instrument temperature. In general, they are not constant and should be re-calculated for each scan. To demonstrate the dynamic features of the calibration coefficients, the  $a_0$ ,  $a_1$ , and  $a_2$  values from the NOAA-15 AMSU-A 1B data of Channel 6 are shown in Figures C-1 for one orbital period. These times series of the calibration coefficients shows the changes which are primarily due to changes in the various component of instrument temperatures over the period. Therefore, they must be calculated at each scan lines. Figure C-2 shows the variations in the RF Shelf and RF Mux temperatures during the same orbital period. It shows that these temperature changed about 1-2K during the orbital period, but it is enough to induce the variations in the  $a_0$ ,  $a_1$ , and  $a_2$  coefficients as shown in Figure C-1. Similarly, the effect of the instrument temperature on the cold space and blackbody radiometric counts is also noticeable. These are shown in Figures C-3 and C-4, where the space and blackbody radiometric counts versus the scan line number are displayed. The variations in the space and warm radiometric counts are mainly due to changes in temperatures of the instrument components. Analysis of these NOAA-15 AMSU-A 1B data shows that the variation of the RF Mux temperature inversely correlates with the blackbody and space radiometric counts as well as channel gains. This is shown in Figure C-5 for Channel 6. In Figure C-5, the left-hand column shows the plots of blackbody counts, space counts, and the RF Mux Temperatures from AMSU-A1-1 versus the scan number over one orbital period. The right-hand column shows the plots of the blackbody counts, space counts, and the channel gain versus the RF Mux temperatures. These plots show the good linear relationships between the three quantities and the RF Mux temperatures.

These analysis results provide us with a better understanding of the AMSU-A instrument performance in space and the pre-launch calibration data.



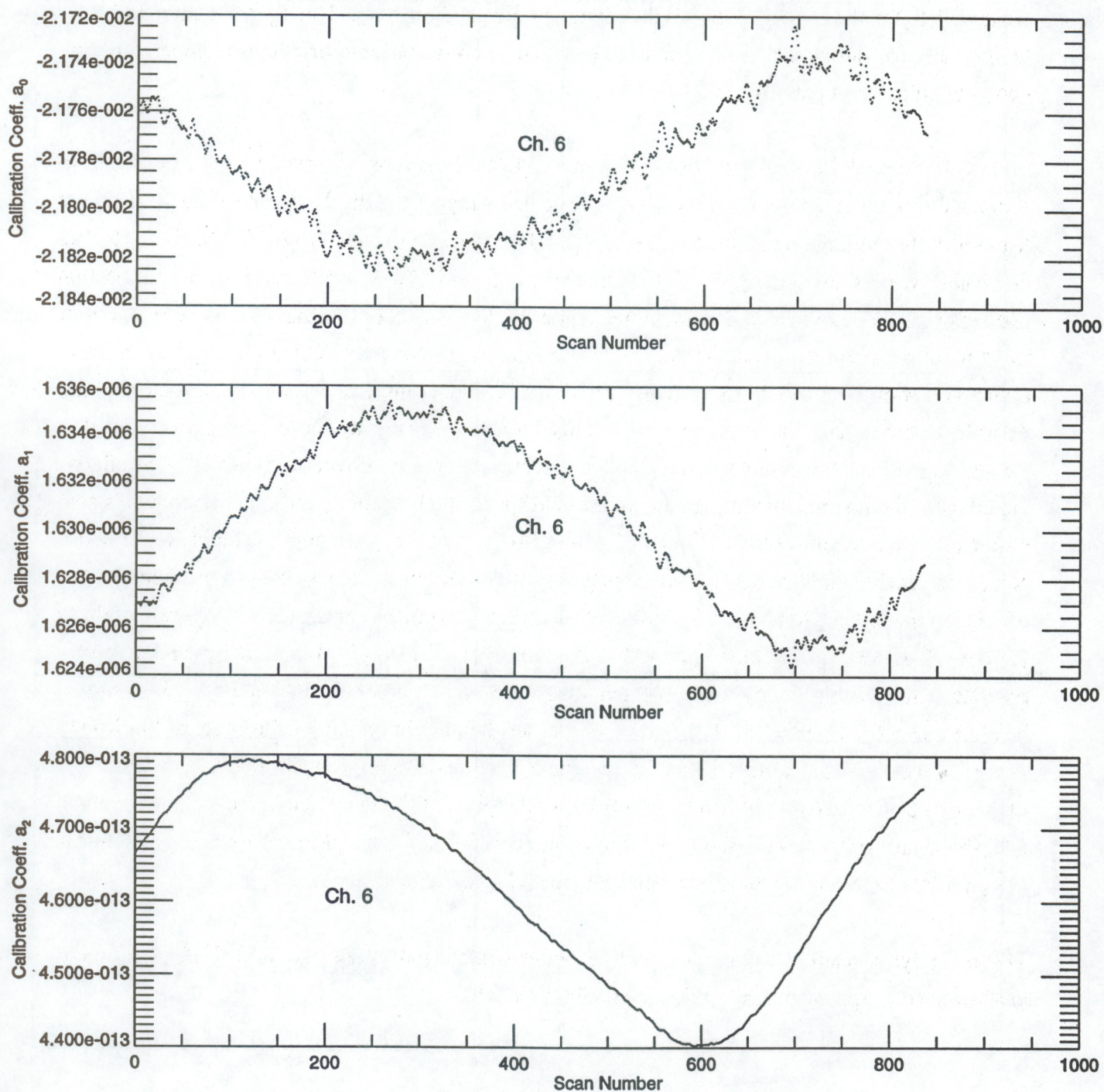


Figure C-1. NOAA-15 AMSU-A: Variation of the calibration coefficients,  $a_0$ ,  $a_1$ , and  $a_2$  values from Channel 6, over one orbital period.



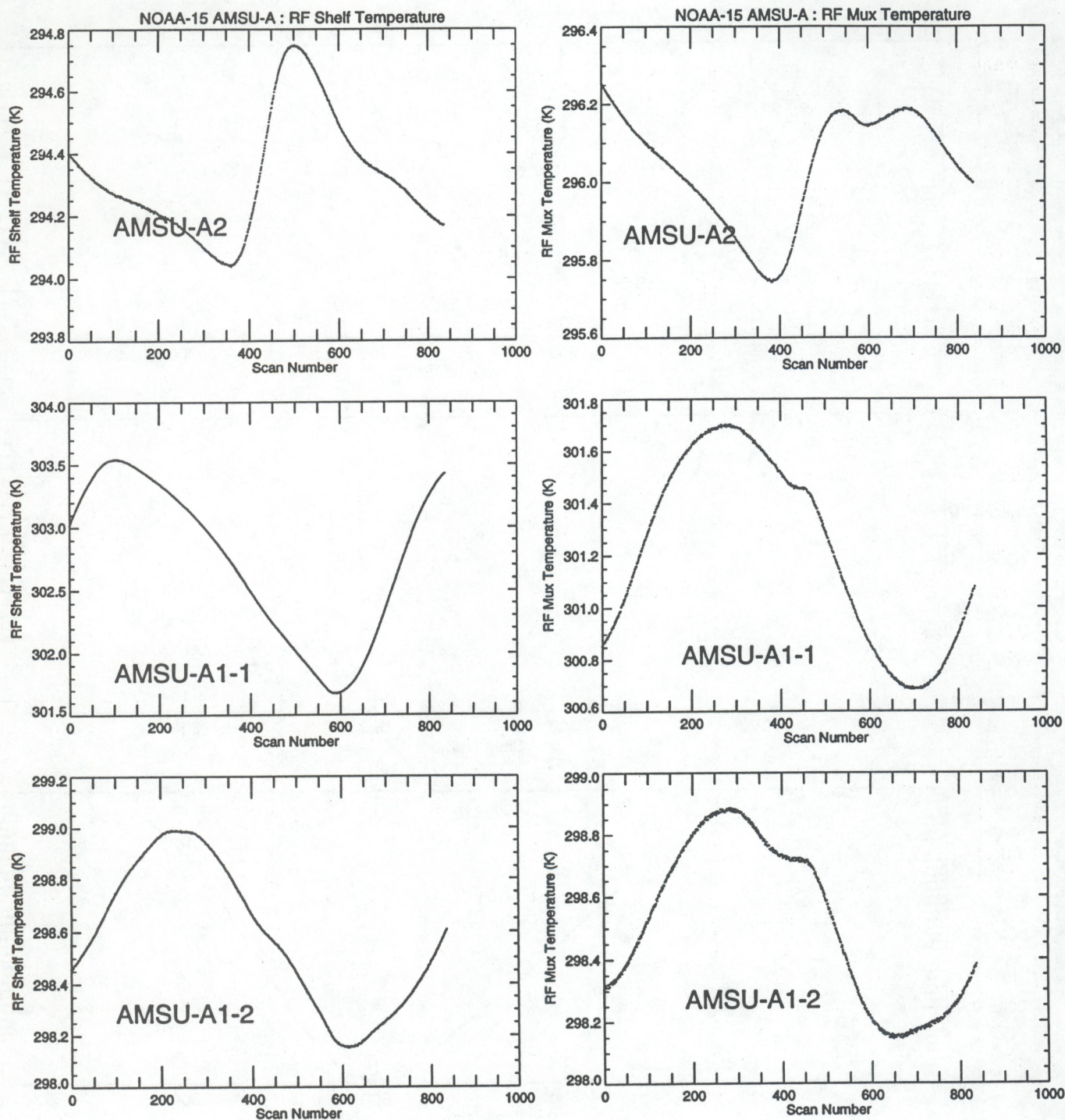


Figure C-2. NOAA-15 AMSU-A: Variation of the RF Shelf and RF Mux temperatures over one orbital period.



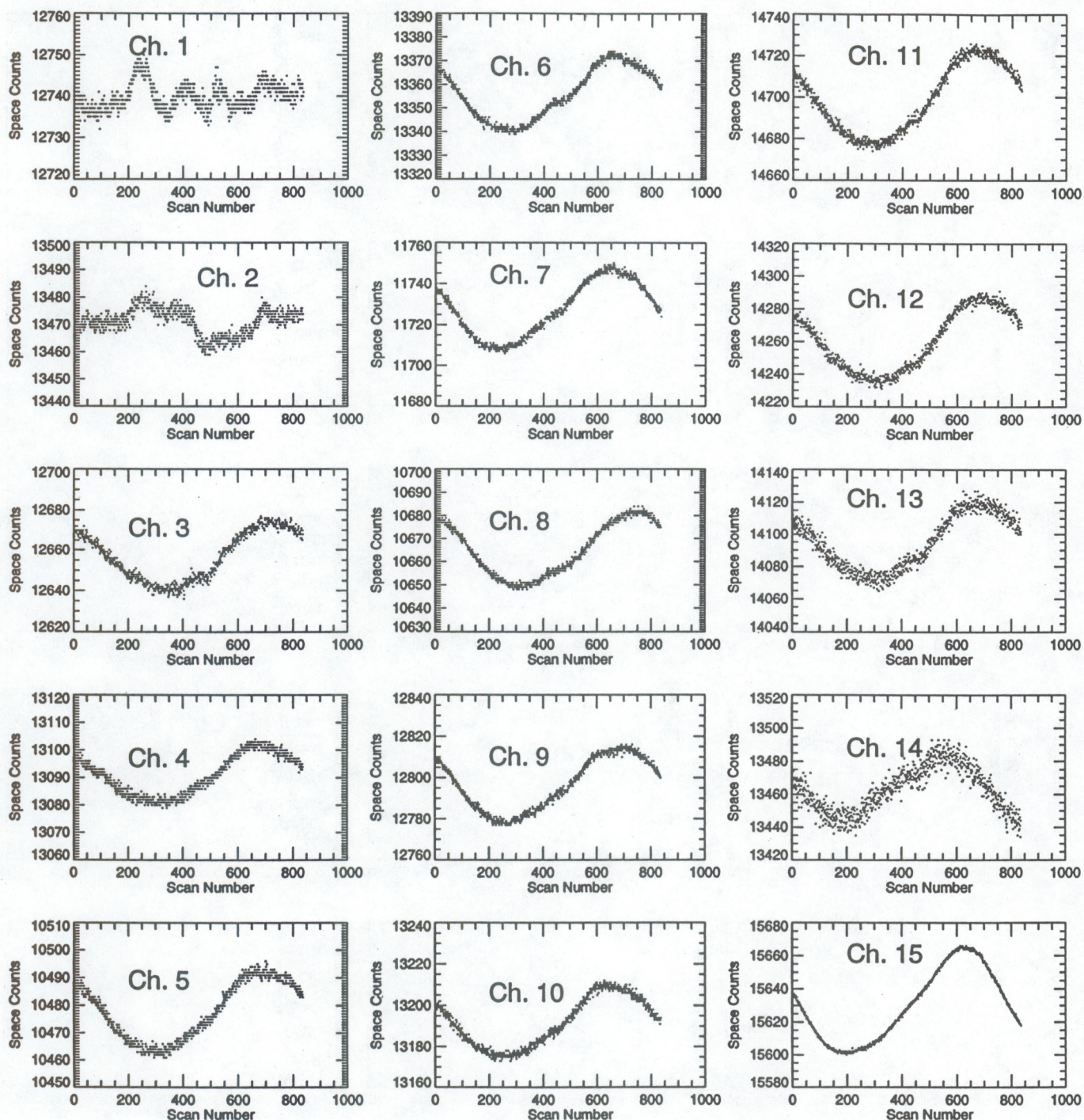


Figure C-3. NOAA-15 AMSU-A: Variation of the space radiometric counts over one orbital period.



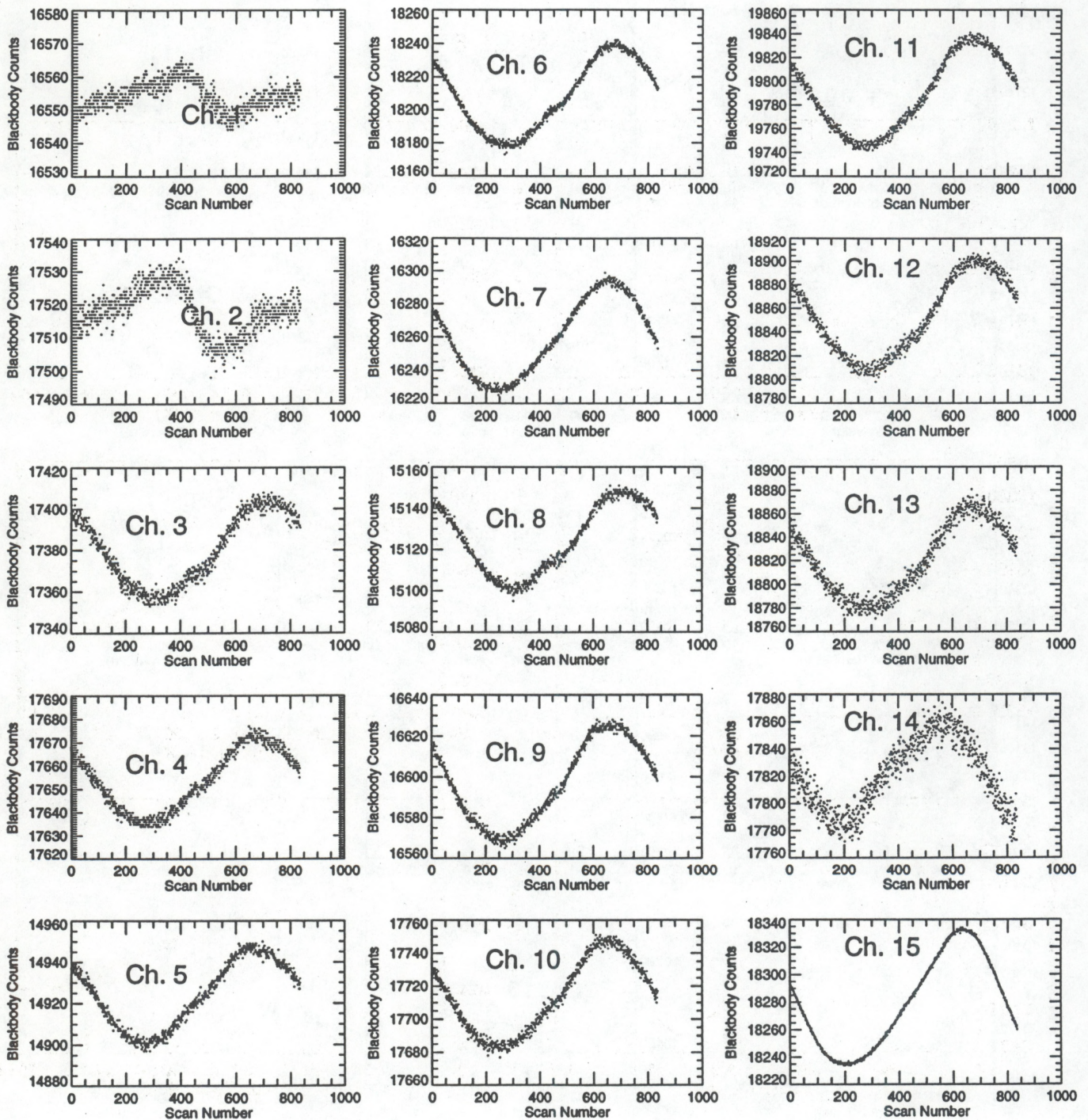


Figure C-4. NOAA-15 AMSU-A: Variation of the blackbody radiometric counts over one orbital period.



## CHANNEL 6

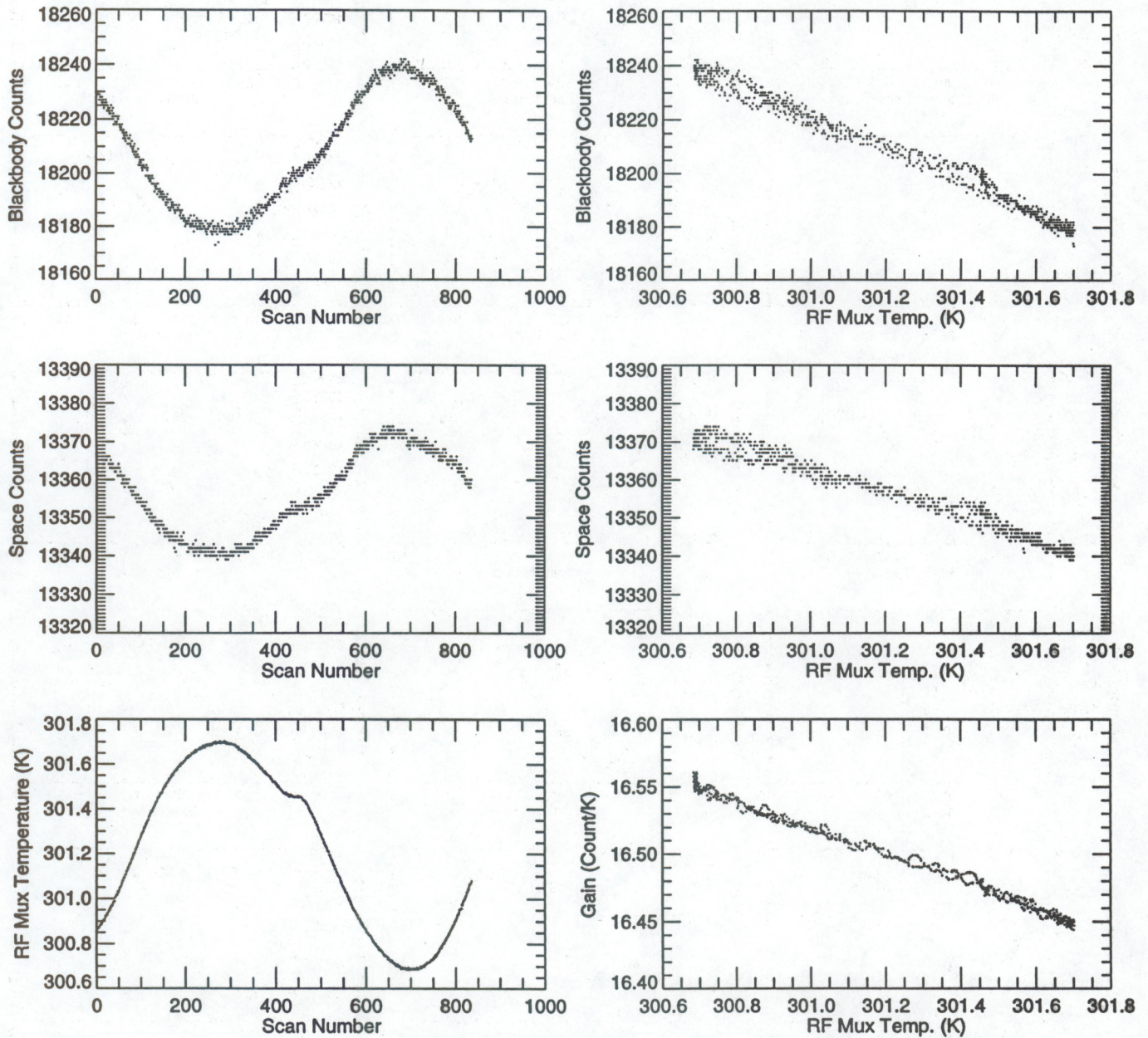


Figure C-5. NOAA-15 AMSU-A: Correlation of the RF Mux temperature with the blackbody counts, space counts, and the channel gain over one orbital period.



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- NESDIS 70 Degradation of the Visible and Near-Infrared Channels of the Advanced Very High Resolution Radiometer on the NOAA-9 Spacecraft: Assessment and Recommendations for Corrections. C.R. Nagaraja Rao (Editor), June 1993.
- NESDIS 71 Spectral Radiance-Temperature Conversions for Measurements by AVHRR Thermal Channels 3,4,5. Paul A. Davis, August 1993.
- NESDIS 72 Summary of the NOAA/NESDIS Workshop on Development of a Global Satellite/in Situ Environmental Database. Edited by K.P. Gallo and D.A. Hastings, August 1993.
- NESDIS 73 Intercomparison of the Operational Calibration of GOES-7 and METEOSAT-3/4. W. Paul Menzel, Johannes Schmetz, Steve Nieman, Leo Van de Berg, Volker Gaertner, and Timothy J. Schmit, September 1993.
- NESDIS 74 Dobson Data Re-Evaluation Handbook. Robert D. Hudson and Walter G. Planet (Eds), October 1993.
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- NESDIS 77 NOAA Polar Satellite Calibration: A System Description. Cecil A. Paris, April 1994.
- NESDIS 78 Post-Launch Calibration of the Visible and Near Infrared Channels of the Advanced Very High Resolution Radiometer on NOAA-7,-9, and -11 Spacecraft. C. R. Nagaraja Rao and Jianhua Chen, April 1994.
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