TOGA/COARE AMMR 92 Data Processing

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The complete set of TOGA/COARE flight data for the 91.65 GHz Airborne Meteorological Microwave Radiometer (AMMR92) contains data from nineteen flights: two test flights, four transit flights, and thirteen experimental flights. The data flights occurred between December 16, 1992 and February 28, 1993. Currently, data from three flights (#'s 930104, 930105, and 930110) is enroute to Georgia Tech for processing, and one data set (from flight # 930114) was lost during archiving. Additional data was obtained on March 2, 1993 while operating the AMMR92 as part of the complete TOGA/COARE compliment of Airborne Microwave Meteorological Sensor (AMMS) and AMMR radiometers after removal from the DC-8 aircraft.

Data collection from the AMMR92 during the first ten flights of TOGA/COARE was performed using the executable code TSK30041. These are IBM PC/XT programs used by the NASA Goddard Space Flight Center (GSFC). During flight # 930110, inconsistencies were found during the operation of the AMMR92 using the GSFC data acquisition system. The displayed and measured data at the instrument did not always agree. Consequently, the Georgia Tech (GT) data acquisition system was used during all successive TOGA/COARE flights.

The inconsistencies first noticed during flight #930110 were found during the data processing to affect the recorded data as well. Errors are caused by an insufficient pre- and post-calibration settling period for the splash-plate mechanism. The splash-plate operates asynchronously with the data aquistion system (there is no position feedback to the GSFC or GT data system). This condition caused both the calibration and the first post-calibration scene measurment to be corrupted on a randomly occuring basis when the GSFC system was used. This problem did not occur with the GT data aquisition system due to sufficient allowance for splash-plate settling.

The two systems use a similar data acquisition algorithm. The GSFC system records a HOT and COLD calibration pair and 56 one-second scene measurements (records) every 61.5 seconds. The GT system operates asynchronously, storing a

HOT and COLD calibration pair and 48 records of ~1.4 seconds each every ~80 seconds. The GT system clock was synchronized with the DC-8 Data Acquisition and Distribution System (DADS) prior to each flight; discrepancies of no greater than six seconds were found at the end of each flight. The errors have been corrected post-flight to within one second of the DADS standard using information recorded manually in-flight.

Due to internal alignment problems the main beam of the instrument was directed ~9.5° forward of the desired broadside look angle (90°) when mounted on the port side of the platform. Although the alignment error could not be corrected in the field, the orientation of the instrument's external mirror was adjusted to reduce polarization mixing. As a result, polarization mixing caused by rotation of the two orthogonal polarizations was less than two percent during level flight. Processing of the AMMR92 data does not correct for the small misalignment of the main beam.

After TOGA/COARE it was also determined that calibration of the instrument was a function of the scene brightness temperature. Therefore, the orientation error in the main antenna beam of the AMMR92 is hypothesized to be caused by misalignment of the internal "splash-plate" responsible for directing the antenna beam toward the scene or toward the calibration loads. Misalignment of the splash-plate is also responsible for "scene feedthrough" during calibration. Laboratory investigations at Georgia Tech found that each polarization is affected differently by the splash-plate alignment error. This is likely to cause significant and unique errors in the absolute calibration of each channel.

Archival of the AMMR92 TOGA/COARE data required correction for the spalsh-plate misalignment. This is accomplished by precisely defining the antenna feedhorn temperature during the internal calibration sequence:

$$
\begin{aligned}
T_{fv}^{(H)} &= \eta_v^{(H)} T_{hot} + \left(1 - \eta_v^{(H)}\right) T_{scene} && (1)\\
T_{fh}^{(H)} &= \eta_h^{(H)} T_{hot} + \left(1 - \eta_h^{(H)}\right) T_{scene} && (2)\\
T_{fv}^{(C)} &= \eta_v^{(C)} T_{cold} + \left(1 - \eta_v^{(C)}\right) T_{scene} && (3)\\
T_{fh}^{(C)} &= \eta_h^{(C)} T_{cold} + \left(1 - \eta_h^{(C)}\right) T_{scene} && (4)
\end{aligned}
$$

where η is the beam efficiency for each calibration load and each polarization, T_{scene} is the unpolarized scene brightness temperature, $T_{fv}^{(H)}$ is the vertical polarization antenna temperature while the radiometer is observing the HOT internal calibration load, and T_{hot} is the kinetic temperature of the HOT load. The four antenna beam efficiencies were determined from two calibrations one during a warm scene brightness temperature (T_{amb}) and one during a cold (77.35 K) scene temperature (T_{lN2}). Using both calibrations:

$$g_\alpha \left(v^{(\gamma)}_{\alpha amb} - v^{(\gamma)}_{\alpha lN2} \right) = \left(1 - \eta^{(\gamma)}_\alpha \right) \left(T_{amb} - T_{lN2} \right) \tag{5}$$

where $\alpha = v$ or h, $\gamma = H$ or C, v is the radiometer output voltage and g_α is the gain (K/v) determined by an external calibration load. Note that the offset term of the calibration is not needed. Now, η_α can be found by:

$$\eta^{(\gamma)}_\alpha = 1 - \frac{g_\alpha \left(v^{(\gamma)}_{\alpha amb} - v^{(\gamma)}_{\alpha lN2} \right)}{\left(T_{amb} - T_{lN2} \right)} \tag{6}$$

The corrected internal gains and offsets using (1 - 4) are:

$$g^{(I)}_\alpha = \frac{T^{(H)}_{f\alpha} - T^{(C)}_{f\alpha}}{v^{(H)}_\alpha - v^{(C)}_\alpha} \tag{7}$$

$$o^{(I)}_\alpha = v^{(C)}_\alpha - \frac{T^{(C)}_{f\alpha}}{g^{(I)}_\alpha} \tag{8}$$

where $^{(I)}$ indicates a calibration determined from the internal calibration standards and T_{scene} is computed using uncorrected in-flight gain and offsets. Feedhorn brightnesses for the TOGA/COARE data flights were calculated according to:

$$T_{f\alpha} = g^{(I)}_\alpha \left(v_\alpha - o_\alpha \right) \tag{9}$$

where $T_{f\alpha}$ is the antenna temperature. The corrected internally derived gain, $g^{(I)}_\alpha$ and offset, $o^{(I)}_\alpha$ are determined from each calibration sequence using (7, 8), and linearly interpolated over time for each scene measurement.

Correction for loss in the antenna lens was also necessary. The antenna temperature with the splash-plate directed toward the scene is:

$$T_{f\alpha} = \mu_\alpha T_{\alpha scene} + \left(1 - \mu_\alpha \right) T_{lens} \tag{10}$$

where T_{lens} is the kinetic temperature of the radiometer's lens and μ_α is the lens efficiency. This is determined by measuring a scene with a well known brightness temperature that is very different than the kinetic temperature of the radiometer's lens such as an absorber placed in liquid Nitrogen (lN_2):

$$\mu_\alpha = \frac{T_{lens} - T_{f\alpha}}{T_{lens} - T_{lN2}} \tag{11}$$

where $T_{f\alpha}$ is determined by the "corrected" gains and offsets (7, 8). The corrected in-flight scene brightness temperature is:

$$T_{scene} = \frac{\mu_\alpha T_{f\alpha} - (1 - \mu_\alpha) T_{lens}}{\mu_\alpha} \tag{12}$$

where T_{scene} is the archived estimate of the actual scene brightness temperature and T_{lens} is determined from in-flight data.

A summary of AMMR92 data processing is given by Table 1 below.

Table 1: Status of calibrated data for TOGA/COARE as of May 6, 1994:

Flight Code	Date(s) Z	Purpose	Data System	Binary Data Files	ACSII Data File	# Records
930101	16-12-92	Test Flight # 1	GSFC	23511716.AMR	TC01.DAT	11536
930102	19-12-92	Test Flight # 2	GSFC	23541805.AMR	TC02.DAT	15118
930103	22-12-92	Test Flight # 3	None	(1)		
930104	04-01-93	Transit to HAFB	GSFC	(2)		
930105	05-01-93	Transit to TVL	GSFC	(2)		
930106	11/12-01-93	Radiation	GSFC	30112140.AMR	TC06.DAT	21166
930107	17/18-01-93	Convection	GSFC	30172307.AMR	TC07.DAT	24358
930108	19-01-93	Convection	GSFC	30180140.AMR	TC08.DAT	23912
930109	25/26-01-93	Radiation	GSFC	30252330.AMR	TC09.DAT	22790
930110	31-01/01-02-93	Radiation	GSFC	30322312.AMR	TC10.DAT	13620
930111	04-02-93	Convection	GT	30351445	TC11.DAT	10715
930112	06-02-93	Convection	GT	30371436	TC12.DAT	14016
930113	08/09-02-93	Convection	GT	30391827	TC13.DAT	12144
930114	10/11-02-93	Convection	GT	(3)		
930115	17/18-02-93	Convection	GT	30481856	TC15.DAT	14880
930116	20/21-02-93	Convection	GT	30511915	TC16.DAT	16176
930117	22/23-02-93	Convection	GT	30531912	TC17.DAT	14880
930118	23/24-02-93	Radiation	GT	30542020	TC18.DAT	15120
930119	26/27-02-93	Transit to HAFB	GT	30571927	TC19.DAT	18480
930120	28-02-93	Transit to Moffett	GT	30591852	TC20.DAT	8976

(1) AMMR not operated.
(2) Data processing in progress.
(3) Binary data file lost during archiving.

4.