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AVHRR AND VISSR SATELLITE INSTRUMENT CALIBRATION RESULTS FOR BOTH CIRRUS AND MARINE STRATOCUMULUS IFO PERIODS

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INTRODUCTION - Accurate characterizations of some cloud parameters are dependent upon the absolute accuracy of satellite radiance measurements. Visible-wavelength measurements from both the AVHRR and VISSR instruments are often used to study cloud characteristics. Both of these instruments were radiometrically calibrated prior to launch, but neither has an onboard device to monitor degradation after launch. During the FIRE/SRB cirrus Intensive Field Operation (IFO), a special effort was made to monitor calibration of these two instruments onboard the NOAA-9 and GOES-6 spacecraft. In addition, several research groups have combined their efforts to assess the long-term performance of both instruments. These results are presented, and a limited comparison is made with the ERBE calibration standard.

DATA - Figures 1 and 2 show calibration results for NOAA-9 AVHRR channels 1 and 2. Figure 3 presents the same information for the GOES-6 VISSR instrument. On each figure, the equation for radiance in terms of instrument gain is shown at the top of the figure. Increasing gain means that instrument sensitivity is decreasing, and the system is deteriorating. All indirect methods are based on radiative transfer calculations from various combinations of model inputs and produce absolute calibration values like the U-2 method. As noted on the figures, the relative methods are anchored to the October 1986 NOAA U-2 absolute results and symbol size indicates the authors' estimates of uncertainty. For sake of brevity, details of the various methods cannot be discussed here but most are generally described in the literature. The NOAA/NESDIS U-2 method and the Scripps indirect method are described in references 1 and 2, respectively. The University of Arizona indirect method is discussed in references 3 and 4. The NASA/GSFC indirect method is based on reference 5. The NASA/LaRC indirect method has not been published, but it uses the radiative transfer model and atmospheric analysis techniques described in reference 6 in combination with surface reflectance and atmospheric measurements made over the Sonora Desert during May 1985 (see reference 7). The ISCCP relative approaches are described in references 8, 9, and 10, and the NASA/LaRC relative method is described in reference 11. Estimated uncertainties in the various methods are summarized below:

METHOD	UNCERTAINTY PERCENT
NOAA/NESDIS U-2	± 5
U. AZ. INDIRECT	± 5
NASA/LaRC INDIRECT	± 7
SCRIPPS INDIRECT	± 8
NASA/GSFC INDIRECT	± 11
NASA/LaRC RELATIVE ANCHORED TO DAY 682 U-2 VALUE	± 2 + (U-2 ERROR)
ISCCP RELATIVE ANCHORED TO DAY 682 U-2 VALUE	± 2 + (U-2 ERROR)

RESULTS - Figure 1 suggests that channel 1 of the NOAA-9 AVHRR instrument degraded by approximately 28 percent over the first 1200 days from launch. Both the NASA/LaRC and ISCCP relative methods appear to give reasonable trends when applied over an extended time period of 2 or more years. When the relative methods are anchored to periodic absolute values, the result is a continuous calibration history that can be used with confidence.

In the period from days 152-257 (May-August 1985), all of the indirect and anchored relative methods agree within estimated uncertainties. One question of some concern is why the channel 1 U-2 results at day 257 do not fall in line with the other methods during that period. (Reference 1 actually reports a slight positive instrument enhancement rather than the usual degradation for that day.) Some insight into this problem may be gained by examining the NASA/LaRC indirect results taken during days 152-159. During that period, the U-2 overflew the Mohawk Valley region, and the NASA/LaRC method was applied using reference 7 data. Figure 4 shows that both the U-2 and NASA/LaRC indirect methods were in reasonable agreement for the channel 1 wavelength range during the May time period. There is a tendency for the indirect method to give slightly higher values at near-infrared wavelengths, however. [Reference 7 describes a deficiency in NBS testing of the field reflectance standard that is the probable cause of this bias at wavelengths either higher or lower than 0.65 micrometers for this particular experiment.] The trend to slight overprediction was confirmed when broad-band results from the indirect method were found to be 7 percent high compared to broad-band ERBE/ERBS values (figure 5). If one compensates for the near-infrared bias, the NASA/LaRC indirect method applied to visible wavelengths is apparently consistent with the ERBE calibration standard. This in turn gives additional confidence in all of the indirect and anchored relative results for the days 152-257 period. For this reason, it is believed that the U-2 point at day 257 is in error by a larger amount than the quoted 5 percent uncertainty.

Figure 2 suggests that channel 2 of the NOAA-9 AVHRR instrument may have been as much as 10 percent degraded immediately after launch and that degradation increased to 28 percent by day 1200. Those values are based on an assumed fit, however, since neither the ISCCP nor the NASA/LaRC relative methods have analyzed AVHRR channel 2.

Figure 3 suggests a sinusoidal degradation of the GOES-6 VISSR instrument. In this case, the ISCCP VISSR values are computed using AVHRR channel 1 gain values in combination with the ISCCP slope ratio in the following equation:

$$G_{8(G-6)} = 0.01966*A*G_{10(N-9,CH\ 1)} \qquad (1)$$

where: $G_{8(G-6)}$ = GOES-6 VISSR gain in terms of 8-bit counts.

$G_{10(N-9,CH\ 1)}$ = NOAA-9 AVHRR channel 1 gain in terms of 10 bit counts.

A = ISCCP slope ratio.

It is believed that the sinusoidal characteristic is partly caused by the fact that the gain often changed weekly by NOAA to correct for banding effects in the cloud images. Additional investigation of GOES degradation is desirable.

The following calibration equations are recommended for satellite data analysis during the FIRE IFO periods:

	CIRRUS IFO	
NOAA-9/AVHRR CH 1:	RAD = - 22 + [0.6060*(10-BIT COUNTS)]	(2)
NOAA-9/AVHRR CH 2:	RAD = - 16 + [0.4000*(10-BIT COUNTS)]	(3)
GOES-6/VISSR:	RAD = - 8 + [0.01015*(8-BIT COUNTS^2)]	(4)
	MARINE STRATOCUMULUS IFO	
NOAA-9/AVHRR CH 1:	RAD = - 22 + [0.6338*(10-BIT COUNTS)]	(5)
NOAA-9/AVHRR CH 2:	RAD = - 16 + [0.4150*(10-BIT COUNTS)]	(6)
GOES-6/VISSR:	RAD = - 8 + [0.01000*(8-BIT COUNTS^2)]	(7)

The following filter bandpass and filtered solar constants are recommended:

	BANDPASS VALUES ....microns....	SOLAR CONSTANTS W/(m^2 sr micron) @ 1 AU
NOAA-9/AVHRR CH 1:	0.117	519.4
NOAA-9/AVHRR CH 2:	0.240	335.2
GOES-6/VISSR:	0.187	526.9

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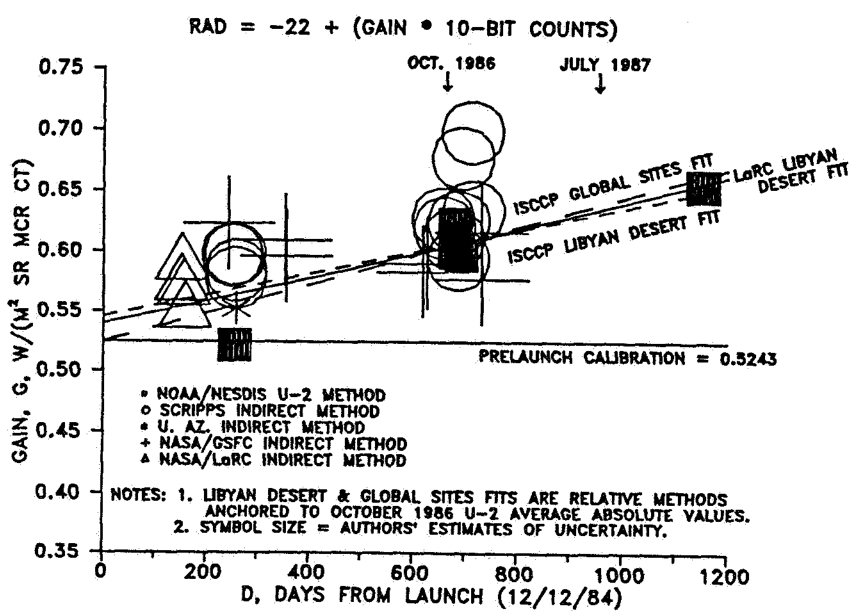

Fig. 1. NOAA-9 AVHRR channel 1 gain.

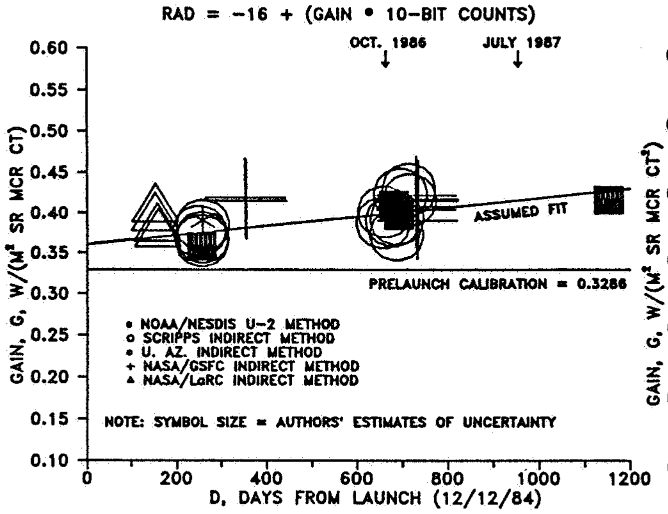

Fig. 2. NOAA-9 AVHRR channel 2 gain.

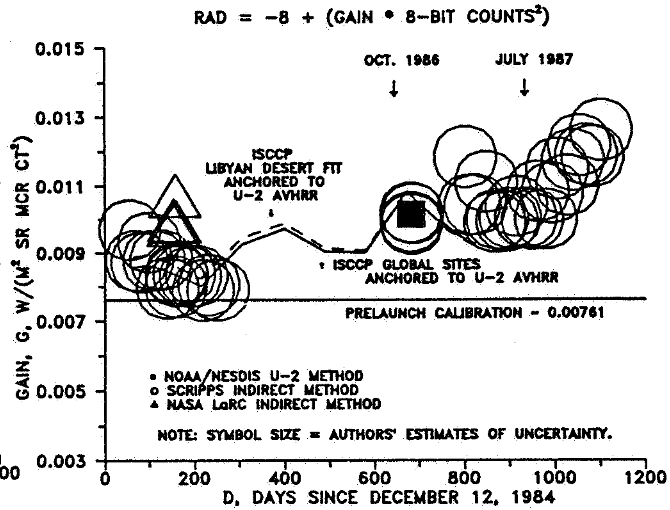

Fig. 3. GOES-6 VISSR gain.

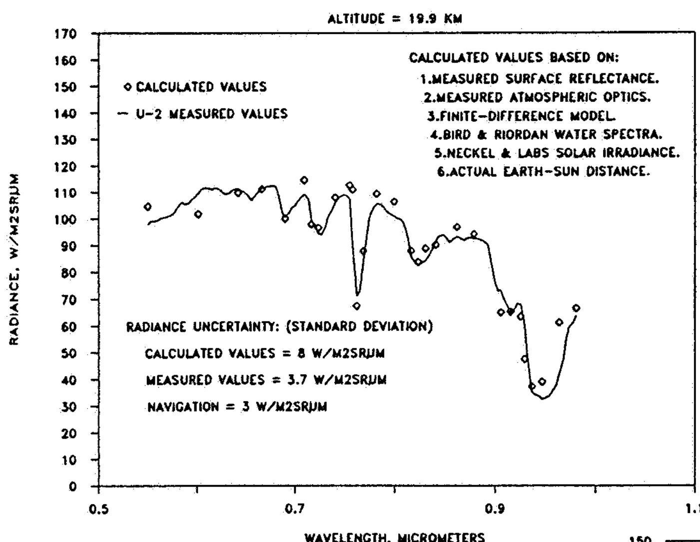

Fig. 4. Comparison of NASA/LaRC indirect method with NOAA U-2 method in May 1985.

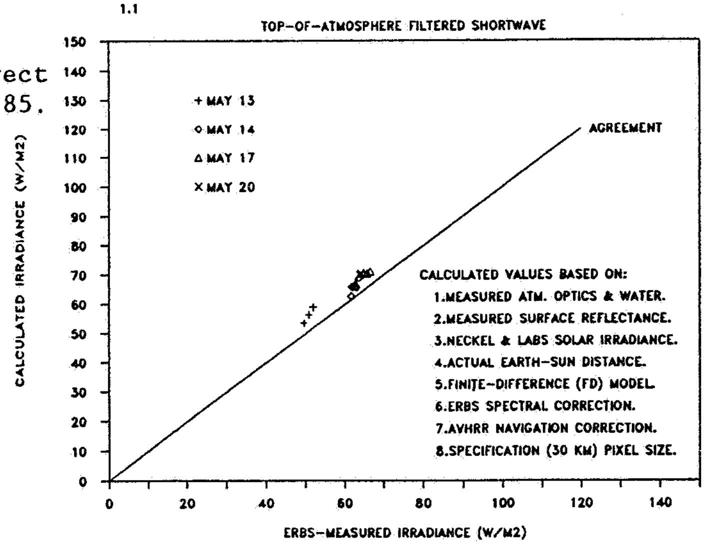

Fig. 5. Comparison of NASA/LaRC indirect method with ERBE/ERBS top of atmosphere irradiances in May 1985.