Radiometer Calibration Trends

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Abstract

Calibrations of Atmospheric Radiation Measurement (ARM) broadband radiometers occur on an annual schedule, made necessary by an expected drift of instrument sensitivity and the possibility of other physical or environmental factors affecting sensitivity. The Southern Great Plains (SGP), Tropical Western Pacific (TWP), and North Slope of Alaska (NSA) field measurement sites use the Eppley Laboratory, Inc. models precision spectral pyranometer (PSP), 8-48, and normal incident pyrheliometer (NIP) for broadband shortwave measurements. Previous studies characterizing PSP sensitivity show that changes are always negative (becoming less sensitive) and are a function of temperature and exposure to sunlight, possibly the ultraviolet portion of the solar spectrum (Wilcox et al. 2001a). This exposure likely causes physical change in the material on the instrument's sensing surface affecting its ability to absorb solar energy. However, in this study we show that the NIP model radiometers do not always follow that trend, and in field use can increase in sensitivity.

The ARM Radiometer Calibration Trailer at the SGP site has been calibrating radiometers since 1997 (Wilcox et al. 1999, 2001b). The networks have calibration spare radiometers at about 50% of the field deployment number to allow for uninterrupted measurements during the two annual calibration events at the Radiometer Calibration Trailer. Thus, each radiometer has been calibrated approximately four times in six years, yielding a unique and extensive calibration dataset under well-controlled conditions. An analysis of the calibration data indicates that model PSP calibrations nearly always follow the expected trends of decreasing sensitivity with field deployment. However, model NIP calibrations show that many instruments either undergo no change in sensitivity or actually increase in sensitivity.

The reason for increasing sensitivity is not known. This poster shows the variability of NIP calibrations, including the unexpected increase in sensitivity for several instruments. This work underscores the need for ongoing radiometer calibrations and continued efforts to analyze, better understand, and characterize the instruments used for ARM measurements.

Methodology

Pyranometers (Eppley model PSP) and pyrheliometers (Eppley model NIP) have typically been calibrated four to five times since calibrations began at the ARM CART site in 1997 (control instruments up to 12 times each). While reviewing calibration results, we saw an expected drop in responsivity for many instruments, but in a few instruments, we saw an unexpected rise in sensitivity. Most of these instruments showing this behavior were the pyrheliometers.

In this study, we sought to determine if trends exist over time for instrument sensitivity. For each instrument, we compared its first calibrated responsivity to each subsequent calibration. The results were plotted as a percent change from the first calibration. Because we expected a change in sensitivity to correlate with time or with length of field deployment, in the results we gave a visual emphasis to the difference between the first and last calibrations.

In the results below, calibration events for each instrument are marked with unique symbols to show the chronology of the responsivities. However, the ARM Program uses a 50% instrumentation redundancy to allow for both calibrations and uninterrupted field measurements. As a result, the instruments in this study have not all been calibrated the same number of times, nor have they all been in the same calibration events. Thus, no attempt should be made to compare anomalous results for one instrument with a similarly marked result for another instrument. It is possible they were not part of the same calibration event.

The manufacturer has repaired several instruments at the SGP site, and the nature of the repair significantly affected the instrument's responsivity. Those instruments have either been removed from the study or the subset of points either before or after the repairs were removed (whichever subset was smaller).

Discussion

Figure 1 shows the distribution of the responsivity changes for pyrheliometers for each calibration event (1997-2002) as a percent change from the first calibration. For ease of displaying the distribution, the instruments have been ordered by increasing magnitude of change between the first and last calibration. The scatter is fairly well distributed around zero, with most of the points within ±0.5%, an expected variation due to random errors. However, at each extreme, points of a greater magnitude are encountered. Note, for example, instrument 29936E6, seventh from the right end: The second calibration (yellow triangle) was nearly identical to the first. The third was up slightly less than one percent, and the fourth was up about 1.5% (see the plot for 29936E6, top of Figure 2 for actual responsivities for the instrument). The second and third are probably not significantly different from the first, but the last point is outside the bounds of expected error and completes a visible trend in the instrument's responsivity history. Instrument 29847E6 (third from the right) has a similar trend. At the far right, 29856E6 shows a significant increase of about 3% in responsivity for the second, third, and fourth calibrations, then another significant increase for the last (nearly 6%). Instrument 30720E6 (eighth from the right) showed a significant decrease in responsivity for the second, third, and fourth calibrations, then increased sharply on the last calibration to a point slightly above the first calibration. Other instruments show similar erratic behavior.

At the other extreme, the seven left-most instruments in Figure 1 show patterns of decreasing sensitivity with time, a group that differs significantly from the bulk of instruments (see plot for 30584E6, bottom of Figure 2, for actual responsivities). Decreases in responsivity of that magnitude are unusual.

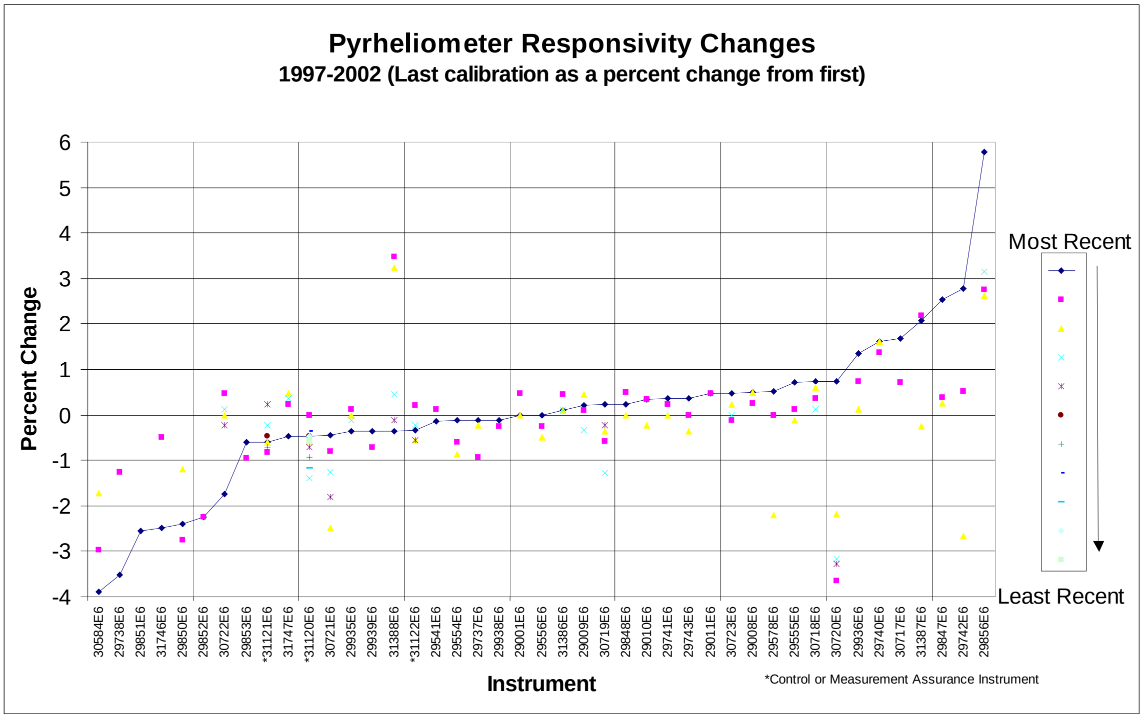

Figure 1. The 1997-2002 pyrheliometer responsivity changes.

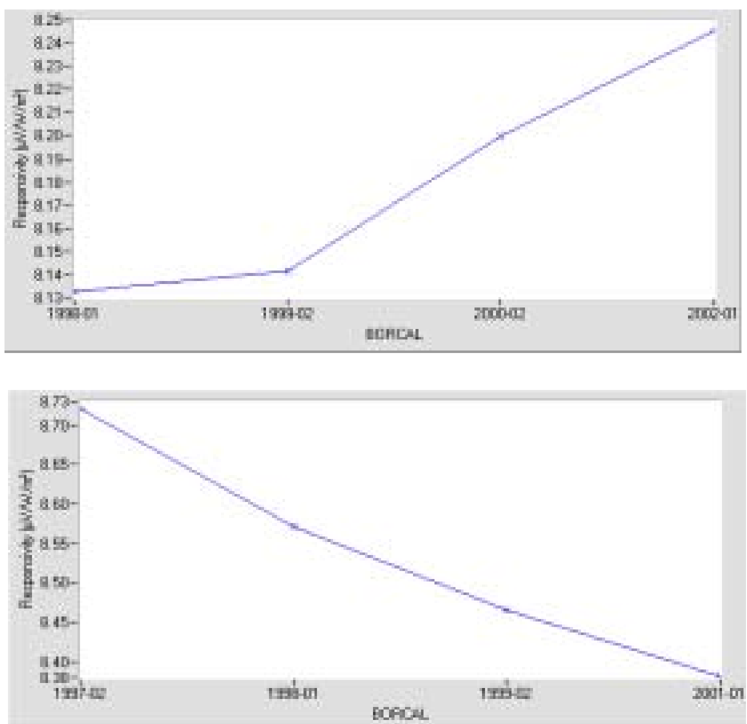

Figure 2. Calibration history for 29936E6, top (factory calibration 8.16), and 30584E6, bottom (factory calibration 8.57).

The calibration control instruments are marked with an asterisk in Figure 1, and all are within ±0.75% of their mean value. These instruments are deployed in every calibration event to show consistency of the process. Note that the actual calibration events are not identified, and that an event portrayed by particular symbol for one instrument may be a different event for another instrument. This is because of the rotating deployment/calibration scheme used at the SGP site.

A comparison of sensitivity changes of PSP instruments to the NIPs over the same 1997-2002 time period is difficult. Figure 3 shows the results for PSPs over the same period of time shown in Figure 2 for NIPs. Here, two distinct populations are evident: One centered near zero and the other sloping down from about -2 to -6.

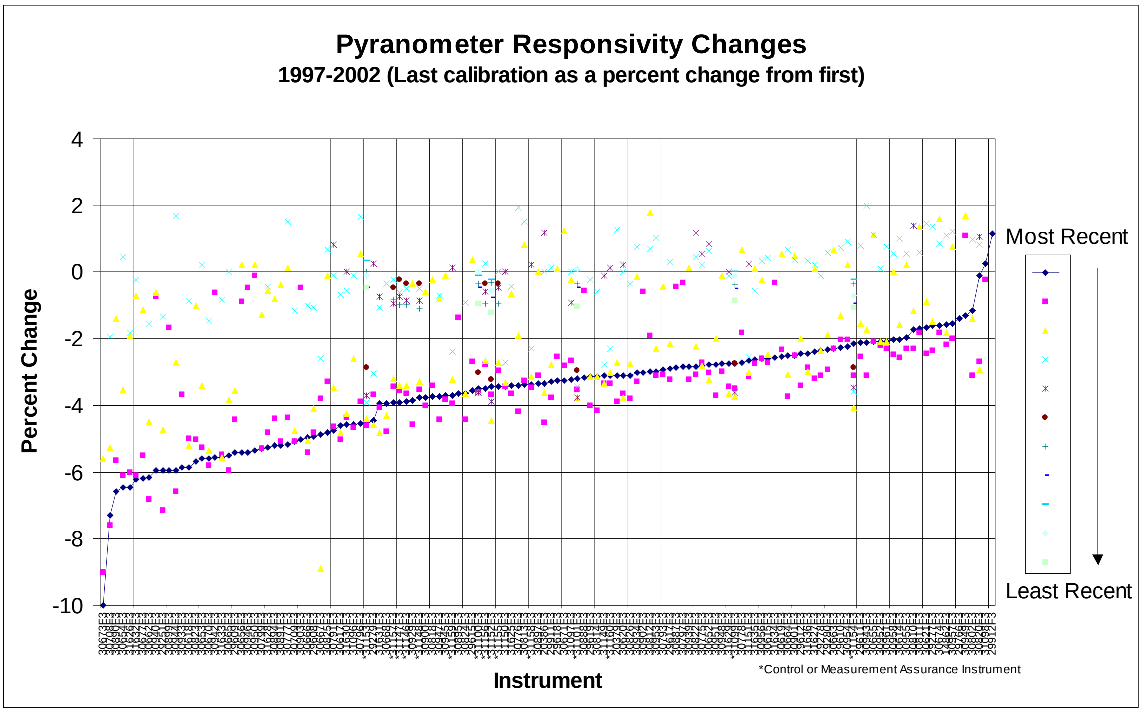

Figure 3. The 1997-2002 pyranometer responsivity changes.

However, the results for pyranometers are clouded by a change in the diffuse reference measurements that began in 2000. This change sought to remove a known instrument offset affecting the calibrations and resulted in lower responsivities for instruments beginning in 2000.

The change in responsivity due to the different diffuse reference and that due to aging or other factors cannot easily be differentiated in Figure 3; hence, this it is included only to illustrate the difficulty in comparing pyranometers to pyrheliometers for the full dataset.

Figure 4, for pyranometers, is similar to Figure 3, but includes only calibration events starting in 2000 when the new diffuse reference measurement method was used. Changes of less than 1.5% are not significant. Several instruments on the left side show degradations greater than that threshold, and based

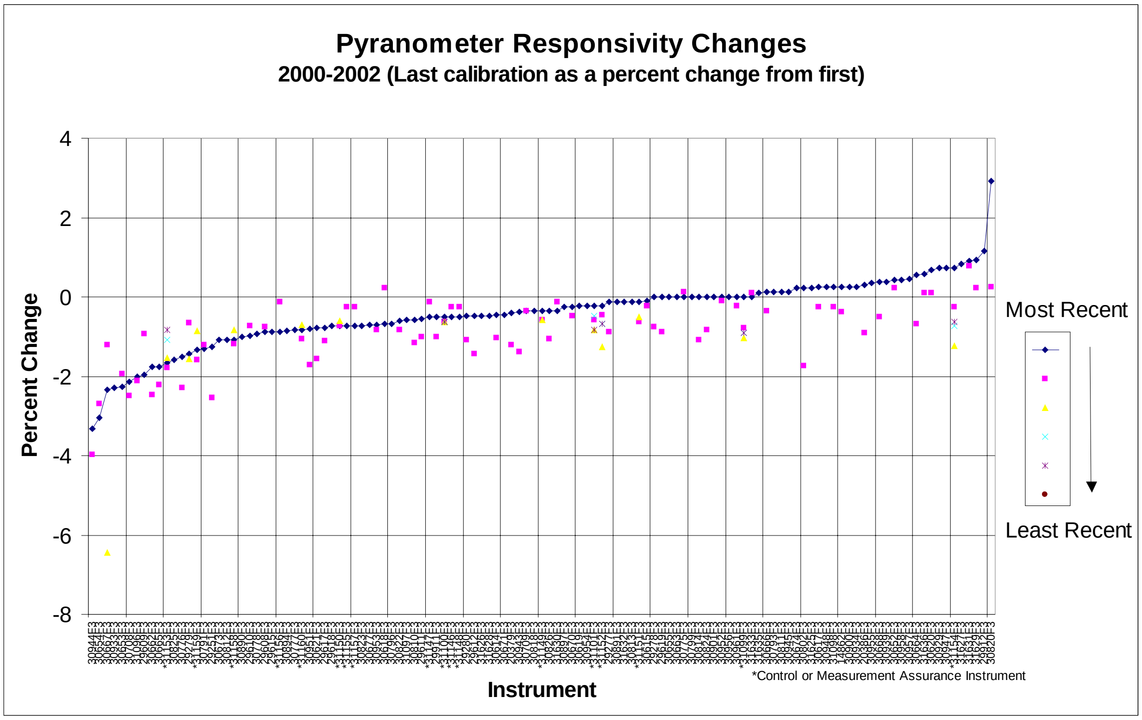

Figure 4. The 2000-2002 pyranometer responsivity changes.

on other studies, this is an expected trend. Only one instrument exceeds the threshold on the right side, increasing a significant 3% between the two last calibrations.

For comparison with Figures 1 and 4, Figure 5 shows the change in responsivities in pyrheliometers over the 2000-2002 period. Although the data points are fewer for each instrument, the results are similar to those in Figure 1 (pyrheliometers 1997-2002).

Conclusions

Based on results from 2000-2002 (using the new diffuse measurement method), pyranometers show an expected decreasing (or insignificant) change in responsivity as a function of deployment time. However, several pyrheliometers show an unexpected increase in sensitivity in both the 1997-2002 period of record and the 2000-2002 subset. Several other pyrheliometers showed an unusual decrease in sensitivity. Among those noteworthy instruments, several show a trend that supports the notion of a severe calibration drift. Others show anomalous or erratic behavior that suggest calibration irregularities or instrument failure. All calibration irregularities have been investigated and no evidence supporting calibration error was found.

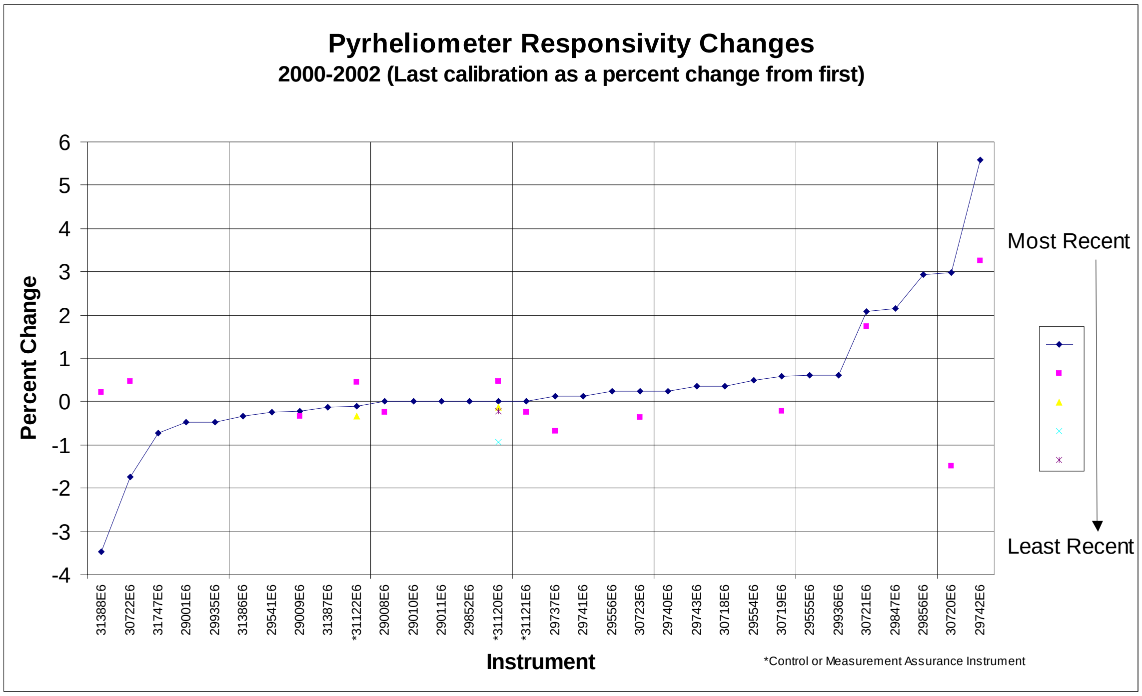

Figure 5. The 2000-2002 pyrheliometer responsivity changes.

The cause of the sensitivity increase is not known, but the following list indicates possible areas of interest to explain the phenomenon:

- errors in the calibration process
- effects from exposure that are possibly unique to the SGP study site
- effects from deployment hazards (for example, transportation to and from the measurement sites)
- problems or variations in the manufacturing process.

Given the rigorous controls on the calibration and manufacturing processes, none of the above are likely candidates for explaining the effect. Thus, one more possibility exists:

- A previously existing but undetected instrument behavior has become conspicuous by the large number of instruments undergoing routine and consistent calibrations in the ARM Program.

Further study would be required to characterize this behavior.

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