Remotely Controlled, Continuous Observations of Infrared Radiance with the CSIRO/ARM Mark II Radiometer at the SGP CART Site

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Abstract

The Commonwealth Scientific and Industrial Research Organization/Atmospheric Radiation Measurement (CSIRO/ARM) Program Mark II infrared (IR) filter radiometer operated continuously at the Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site for a period of five weeks. Data of high quality were obtained by remote operation and data transfer with no evidence of spurious noise or interference. The speed of the radiometer, with 1-second time constant, ensured detection of rapid variations in broken clouds.

Introduction

The CSIRO/ARM Mark II IR filter radiometer was developed from the previous Mark I prototype as a stand-alone narrow-beam fast filter radiometer for taking continuous measurements at an ARM site. The CSIRO/ARM Mark I was a more sophisticated offshoot of the original narrow-beam CSIRO filter radiometer (Platt 1971) that made many observations in combination with the lidar/radiometer (LIRAD) method (e.g., Platt et al. 1987) and observed clouds from an aircraft together with providing microphysics measurements (Platt 1976). It also provided the first aircraft observations of the water vapor continuum absorption (Platt 1972).

The CSIRO/ARM Mark I radiometer was used to make LIRAD observations in the ARM Pilot Radiation Observation Experiment (PROBE) (Platt et al. 1998), in Papua New Guinea, and the ARM component of the Maritime Continent Thunderstorm Experiment (MCTEX) (Platt et al. 2002a,b) on the Tiwi Islands, Northern Territory, Australia.

The CSIRO/ARM Mark II Radiometer

The CSIRO/ARM Mark II radiometer has been described in previous proceedings (Platt et al. 2000). It has a Newtonian optical system, three narrow-band filters, and uses off-axis paraboloids to focus the radiation on the 1-mm dimension HgCdTe-cooled detector. The CSIRO/ARM Mark I detector was cooled by a liquid nitrogen Dewar that had to be replenished every few hours. The CSIRO/ARM Mark II uses a Stirling-cycle cooler Dewar that cools the detector continuously, thus allowing for remote operation.

The CSIRO/ARM Mark II radiometer includes a computer processor that operates the system and provides a virtual screen for viewing radiometer operation. All that is required for operation is a keyboard and a monitor. The CSIRO/ARM Mark II filters are at wavelengths of 8.62 ± 0.2 μm, 10.86 ± 0.25 μm, and 12.04 ± 0.27 μm, and the field of view can be adjusted from 2 to 20 milliradians.

The radiometer is calibrated sequentially by two blackbodies, one heated to about 50°C and the other at ambient temperature, which is normally about 20°C in a temperature-controlled room. Figure 1 shows the radiometer without its cover and the calibration chamber protruding from the front. The latter contains a 45° gold-plated mirror that points at either of the two blackbodies or the zenith atmosphere and is controlled by the internal software and hardware.

Observations at the SGP CART Site

The radiometer was situated in the new Guest Instrument Facility at the SGP CART site, employing an instrument bay built out from the trailer and containing a rain-sensitive hatch. The radiometer is shown in place in Figure 2. It was set up using the local keyboard and then controlled remotely through computers at both Colorado State University in Fort Collins and CSIRO Atmospheric Research in Aspendale, Australia. Observations were taken continuously between June 14 and July 19, 2001.

Figure 3 shows raw calibration and radiometer counts for one 24-hour period on July 14, 2001. The hot calibration blackbody had a control setting that changed stepwise at times. The chopper reference blackbody, against which the signal is chopped, is maintained at a constant temperature of about 40°C. The ambient blackbody is at room temperature. An insulated chimney around the zenith direction isolated the hatch from the room, as shown in Figure 2. A fan to circulate room-temperature air around the ambient blackbody had not yet been installed, so the "ambient" temperature cycled around the external temperature of about 30°C. A damped cooling cycle observed during daylight hours is still visible on the ambient temperature trace. The calibration cycle was run frequently to test the stability of the system. The period of this cycle, controlled by software, could be adjusted to a much longer time between calibrations, if desired. Figure 4 shows the calculated gain and offset signal and calibration signal plotted against blackbody temperature. The standard deviation of the signals over one calibration cycle indicated values that should be rejected. These occurred occasionally due to software timing errors.

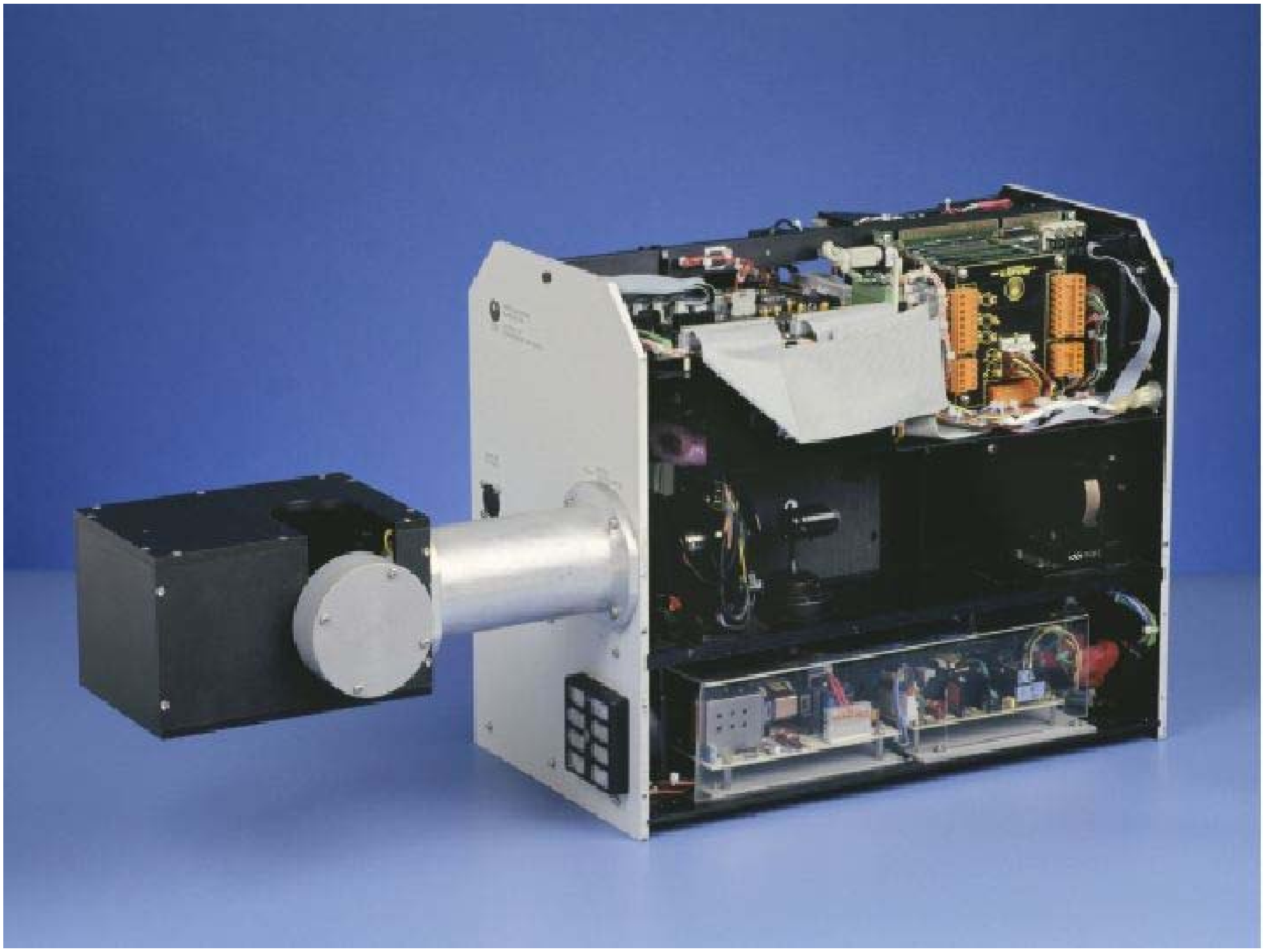

Figure 1. The CSIRO/ARM Mark II Radiometer with cover removed. The calibration chamber is on the left outside the main box; this also contains the 45° mirror for directing the radiation from the calibration sources or the zenith view to the input aperture. In the main box, the chopper assembly is on the left, the secondary mirror is next, and the primary mirror is on the right.

Several days of IR radiance (10.86 μm) are shown in Figures 5 to 7 together with time-height images of micropulse lidar (MPL) backscatter. The microwave radiometer (MWR) water vapor path is also plotted, together with the IR radiometer gain and offset. Broken cloud is seen in several patches in Figure 5 (July 14), and the radiometer is seen to follow the rapid variations in cloud radiance. The signal from cirrus is only just visible at this scale but shows up at better vertical resolution in the radiance scale.

Cirrus on July 9 (Figure 6) shows a strong radiance return at times during nighttime hours when the MPL was profiling the cirrus. The sky is clear to the MPL after 0700 Universal Time Coordinates (UTC), with a very thin high layer of cirrus between 1500 to 1800 UTC. During afternoon hours after 1800 UTC, there are considerable fluctuations in the radiance output, due to fluctuations either in water

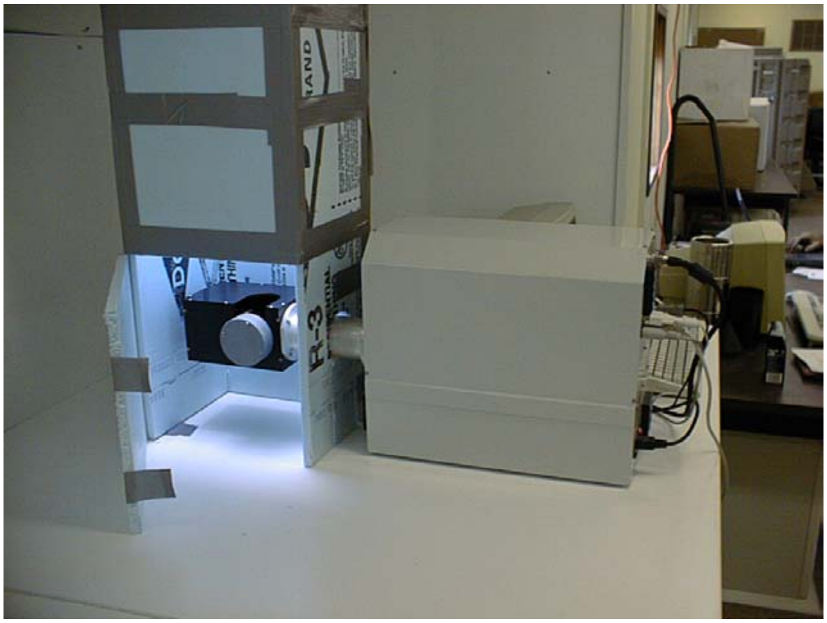

Figure 2. The CSIRO/ARM Mark II Radiometer installed in the instrument bay in the SGP Guest Instrument Facility during the 2001 deployment. The calibration chamber is visible inside the temporary chimney.

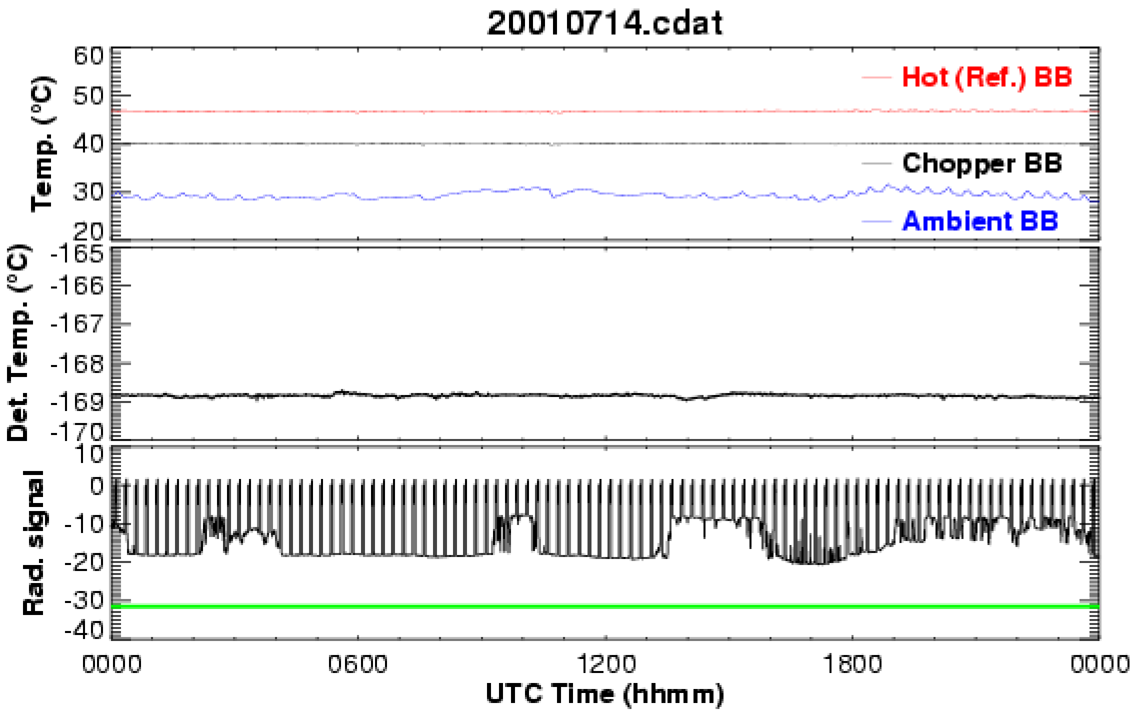

Figure 3. Blackbody temperatures (°C) (top), detector temperature (°C) (middle), and raw radiometer data (kilocounts) (bottom) for July 14, 2001. Calibration periods are visible as spikes in the radiometer data. The green bar indicates operation at 10.86 μm.

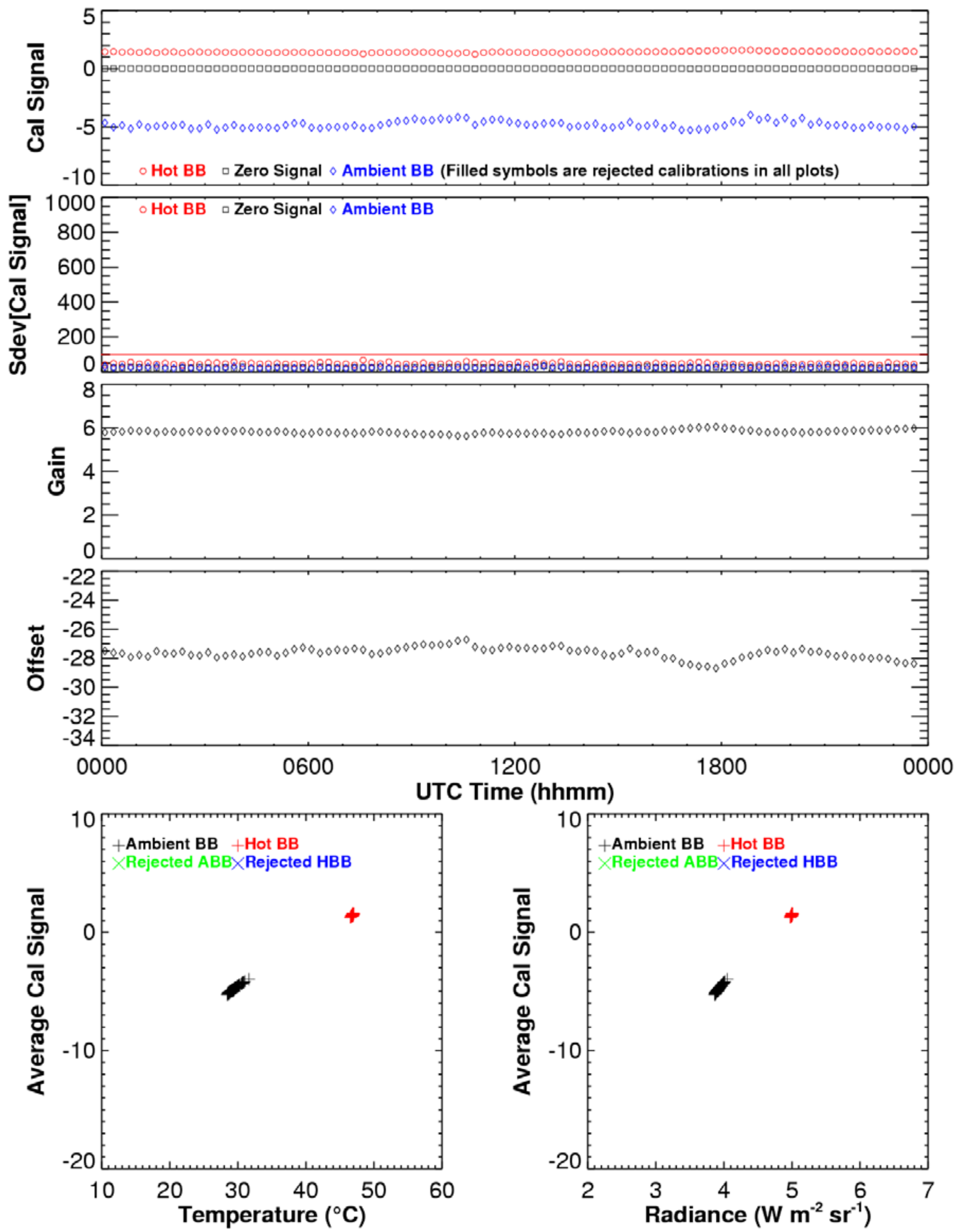

Figure 4. Calibration data for July 14, 2001. The top four plots show a data point for each calibration (set at 15-minute intervals here). (Units are kilocounts, counts, kilocounts / [W m^{-2} sr^{-1}], and kilocounts.) The bottom two plots show calibration signals (kilocounts) as functions of temperature and radiance.

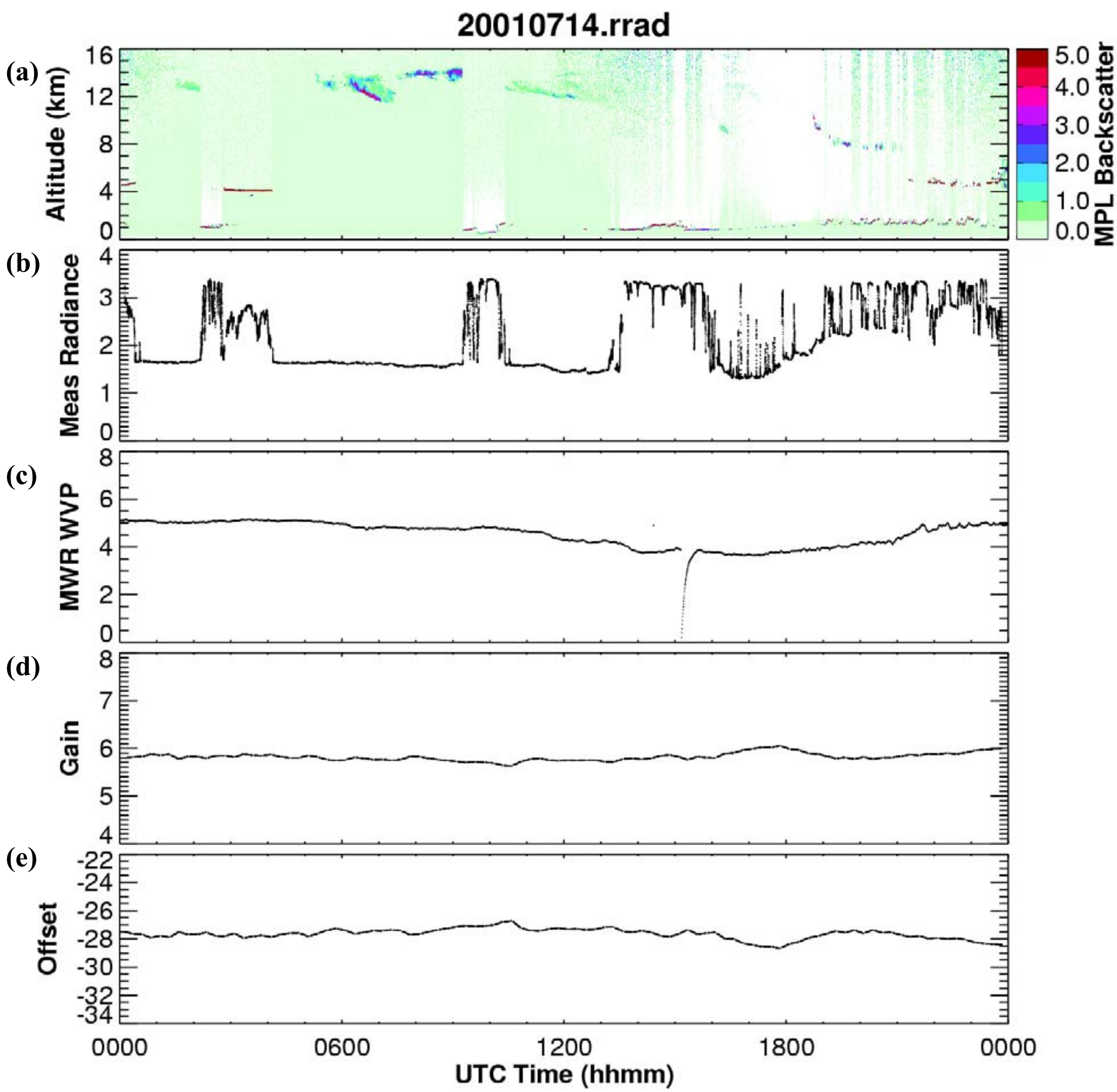

Figure 5. Measurement data for July 14, 2001: (a) MPL backscatter (counts μs^{-1} km^2) (uncalibrated), (b) measured IR radiance (W m^{-2} sr^{-1}), (c) MWR water vapor path (cm), (d) IR radiometer gain (kilocounts / [W m^{-2} sr^{-1}]), and (e) IR radiometer offset (kilocounts).

vapor path or in the temperature structure. The water vapor path as given by the MWR follows the fluctuations in radiance very closely, indicating that it is primarily a water vapor effect. Presumably, (dry) convection plumes during the afternoon hours were responsible. These fluctuations were characteristic of afternoon periods generally, unless clouds intervened.

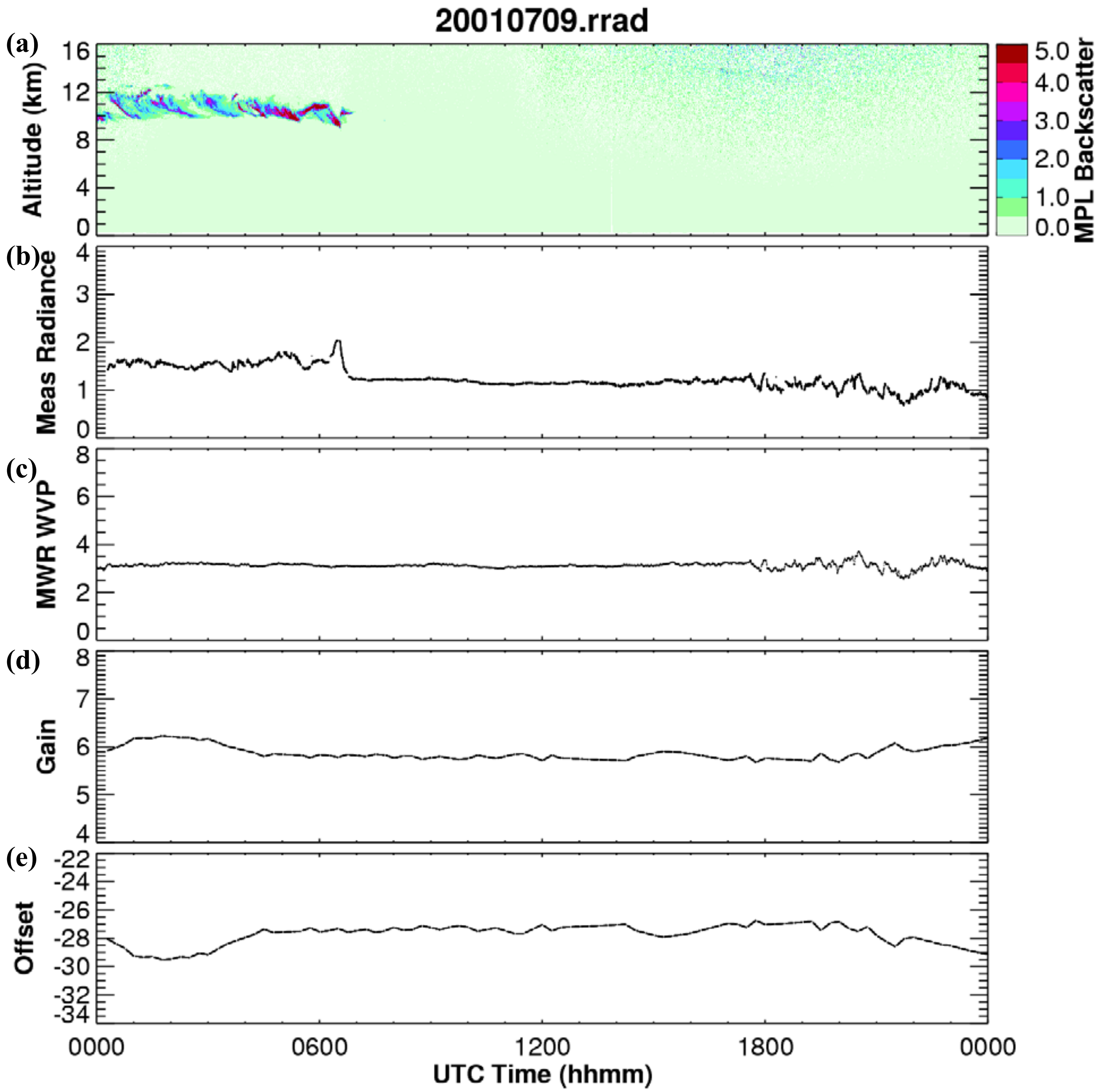

Figure 6. Measurement data for July 9, 2001 (same quantities as Figure 5).

Figure 7 shows an interesting case on June 21, which was one of the few rare occasions when the hatch was closed due to rain. The MPL and radiometer show an approaching front and a period of rain, followed by a clearing and steady increase in the cloud base height, with decreasing but fluctuating radiances. The radiometer and MPL hatches appeared to close and open at different times. The water vapor radiance drops dramatically after the front and in fact remains low for several days; this is mirrored by the MWR, showing a rapid drying out after the front.

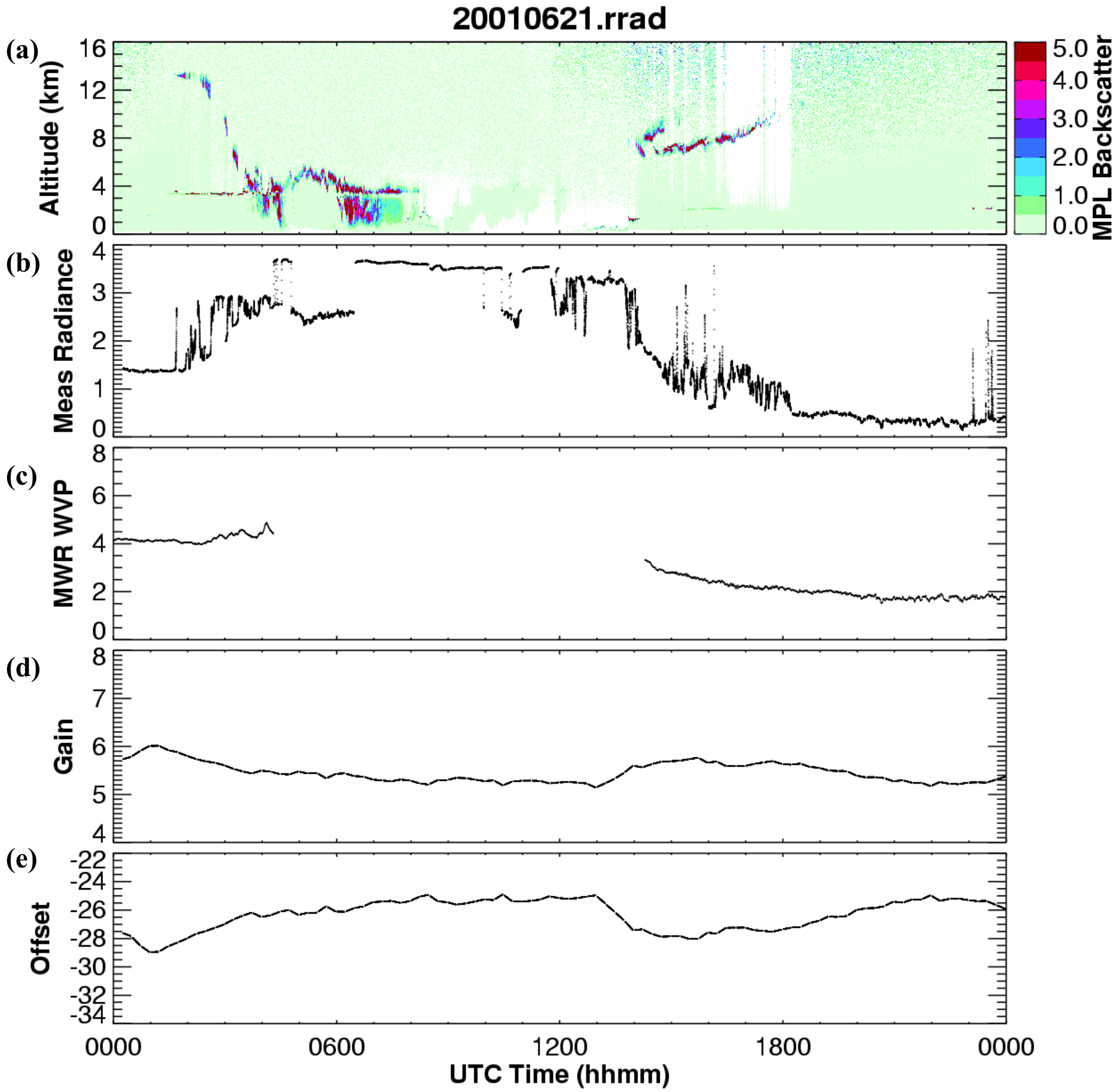

Figure 7. Measurement data for June 21, 2001 (same quantities as Figure 5).

The observations were terminated when a computer software/hardware problem developed and the radiometer was returned to CSIRO Atmospheric Research for maintenance. The radiometer is a prototype Stirling-cycle instrument, and certain upgrades are required. However, the reliability and sensitivity of the instrument is evident from the five weeks of data obtained at the SGP site continuously, with no spurious noise evident on the trace. The calibration also appears to be stable.

Summary

The behavior of the mean radiometer gain and standard deviation is shown in Figure 8. The standard deviation is no more than a few percent of the gain, and the gain varies from day to day by about the same amount. The daily minimum detectable radiance (MDR) for a one-second time constant is also shown. The radiometer started somewhat noisy and took several days to stabilize, but then the MDR stayed very constant. The value of 4.5 mW m^{-2} sr^{-1} $Hz^{-1/2}$ is slightly higher than the value measured in MCTEX for the Mark I radiometer (Platt et al. 1998).

The instrument was controlled and the data recorded either at the Department of Atmospheric Science, Colorado State University, or at CSIRO Atmospheric Research, Aspendale, Australia, indicating the ease of remote operation. Thus, the data could be recorded and controlled at a remote laboratory from any ARM site where Internet service is available. Alternatively, the data could be acquired and archived locally.

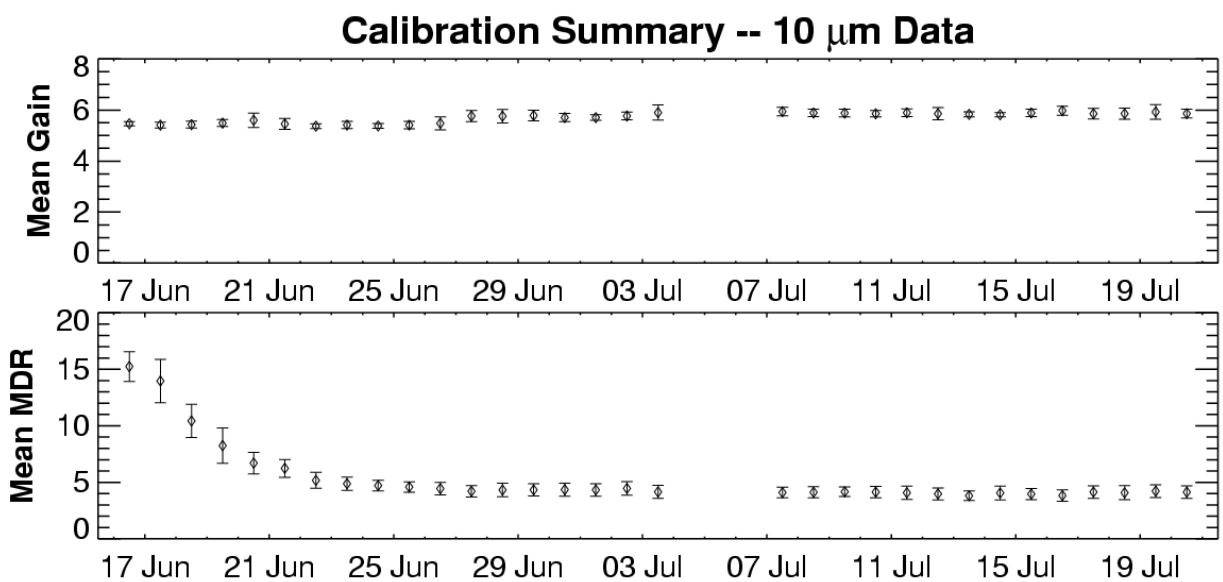

Figure 8. Calibration summary for operation at 10.86 μm during the five-week measurement period. The daily mean and standard deviation of the gain (kilocounts / [W m^{-2} sr^{-1}]) are shown in the upper plot; the mean and standard deviation minimum detectable radiance (mW m^{-2} sr^{-1}) for a one-second time constant are in the lower plot. The radiometer was operated at different wavelengths during the three-day gap around July 5.

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