ARM TR-058

Multi-Filter Radiometer Handbook

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1. General Overview

The multi-filter radiometer (MFR) is simply the head from a multi-filter rotating shadowband radiometer (MFRSR) mounted on a tower pointing at the surface. Like the MFRSR, it has six narrowband channels (415, 500, 615, 673, 870, and 940 nm) and one broadband channel. Pointing the head at the surface provides spectral measurements of reflected irradiance. Measurements are taken every 20 seconds. No averaging is performed.

2. Contacts

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2.2 Instrument Developer

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3. Deployment Locations and History

Table 1. MFRSR Status as of January 1, 2005

Site	Collect Data	Ingest Data
NSA C1 (Barrow) @ 10 m	YES	YES
NSA C2 (Atqasuk) @ 10 m	YES	YES
SGP C1(Central Facility) @ 10 m	YES	YES
SGP C1 (Central Facility) @ 25 m	YES	YES
TWP C1 (Manus) @ 10 m	YES	YES
TWP C2 (Nauru) @ 10 m	YES	YES
TWP C3 (Darwin) @ 10 m	YES	YES

4. Near-Real-Time Data Plots

See the MFRSR General Plots.

See the MFR General Plots.

5. Data Description and Examples

5.1 Data File Contents

5.1.1 Primary Variables and Expected Uncertainty

As mentioned above, the primary quantities measured by the system are:

- Six wavelengths of reflected solar spectral irradiance (W m^{-2} nm^{-1}).

The spectral data are at wavelengths of 500, 615, 673, 870, and 940 nm. The measurements at each wavelength are made by a single filtered detector with a nominal 10-nm full width at half maximum (FWHM) bandwidth.

Table 2. Wavelengths of Narrowband (10-nm) Filters Used in the MFRSR, and Main Trace Species Measured (Michalsky et al. 1995).

Wavelength (nm)	Trace Species
415	aerosol
500	aerosol, ozone
615	aerosol, ozone
673	aerosol, ozone
870	aerosol
940	water vapor

Ozone abundances may be inferred by measurements made by the 500-, 615-, and 673-nm channels. These wavelengths, particularly the 615- and 673-nm wavelengths, are influenced by the Chappuis band of ozone [Goody and Yung 1989). Water vapor primarily affects the 940-nm channel. Rayleigh scattering most strongly affects the lower wavelength channels. This phenomenon is well understood and, therefore, can be removed from an analysis of the optical depth measurements made at all wavelengths.

The uncalibrated silicon detector provides a measure of the:

- Reflected broadband solar irradiance (counts).

These quantities are uncalibrated and reported in “counts.” Note that the actual output of the instrument is millivolts, and the use of “counts” is historical and has been attached to the MFRSR (and related instruments) since it was developed. The counts are linearly scaled using broadband radiometers to be roughly equivalent to W m^{-2}. Zhou et al. (1995) discusses the proportionality between the MFRSR broadband channels and broadband irradiances measured by World Meteorological Organization (WMO) first-class thermopile radiometers.

5.1.1.1 Definition of Uncertainty

The following notes are from the MFRSR instrument pages, but because the MFR is merely a MFRSR head, they are included as they relate to the MFR.

Note about MFRSR calibration as of May 30, 2000:

We have long suspected that the amplitude of measured irradiances from the MFRSR is sensitive to the ambient temperature. For example, if one examines a year-long time series of so-called "Ios" (top-of-atmosphere (TOA) values derived from Langley regressions, a sinusoidal pattern in the time series will be seen. The period of this pattern is exactly one year; the peak of the sine wave corresponds to the warmest part of the year while the valley corresponds to the coldest part of the year.

This pattern, in itself, is not sufficient evidence to implicate sensitivity to temperature. However, we retrieved the MFRSR head associated with these data, and we put the head and logger board in an “environmental chamber” and measured the temperature responsiveness of the system. The responsiveness can be characterized by temperature coefficients for each wavelength channel; these coefficients indicate about a 1 to 2% change in MFRSR output for each 1-degree change in head temperature. Typically, the MFRSR head temperature changes about 2 degrees over a diurnal period and about 5 degrees over the year. Therefore, the potential for output fluctuations over the course of a year may be as high as -+ 5%. If we consider the atmosphere to be gray, the temperature sensitivity errors induce an equivalent broadband error of about +- 50 w/m^2 error (by contrast, a drifting filter may contribute errors on the order of 500w/m^2!!). In short, the temperature sensitivity errors may be significant.

After measuring the temperature sensitivity we devised a way to correct the data based on the measured temperature coefficients. When these corrections were applied, the sinusoidal pattern in the MFRSR Ios disappeared, and the calibration stability of the MFRSR was essentially flat over the entire year. Furthermore, the temperature-corrected MFRSR data was used to drive a broadband model and the output of this model was compared with broadband measurements. In many cases, the use of temperature-corrected MFRSR data (as opposed to the uncorrected data) caused the agreement between the model and the broadband data to improve significantly. (Note: these calculations are not yet finished, so we can't be sure this conclusion will hold). All this evidence taken together strongly suggests that the temperature sensitivity is real.

Independent evidence of the temperature sensitivity comes from MFRSR data collected as part of old, defunct, non-Atmospheric Radiation Measurement (ARM) programs in which the sinusoidal wave had been observed but not explained until now. Again, in these old data sets the peak of the sine wave occurs during the warm times of the year and the valley into the coldest times of the year.

We (Pacific Northwest National Laboratory [PNNL], Yankee Environmental Systems, and the Atmospheric Sciences Research Center [ASRC]) don't know what's causing this problem, and we don't know if the magnitude of the problem is different from head to head. The analysis and temperature chamber operation is costly, and we don't have the time or budget needed to get to the bottom of this problem. The data can be partially corrected by using monitoring the Ios from Langley regressions, but this is at best, an imperfect solution.
Yankee knows about this problem, and they may try to fix it (this could take a very long time).

Note about MFRSR calibration as of November 1, 1999:

Installation of new interference filters has significantly reduced the calibration drift. To date, the calibrations (for MFRSRs that contain the new filters) appear to be very stable. The new units have been installed at the E13 and C1 sites at the Southern Great Plains (SGP), and at all Tropical Western Pacific (TWP) and North Slope of Alaska (NSA) sites.

Note about MFRSR calibration as of March 11, 1998:

As of 11 March 1998, the calibration of the MFRSR is problematic. For some channels (i.e., wavelengths), the calibration drifts significantly with time. For other channels the calibration is stable but not very accurate; in some cases, the error in the spectral fluxes may be as much as 50%. The poor calibrations affect some of the flux measurements but do not affect any of the optical depths derived from the MFRSR.

5.1.2 Secondary/Underlying Variables

This section is not applicable to this instrument.

5.1.3 Diagnostic Variables

This section is not applicable to this instrument.

5.1.4 Data Quality Flags

-9999.0 signifies missing data.

See MFRSR, MFR10M, and MFR25M Data Object Design files for the ARM netCDF file header descriptions.

5.1.5 Dimension Variables

This section is not applicable to this instrument.

5.2 Annotated Examples

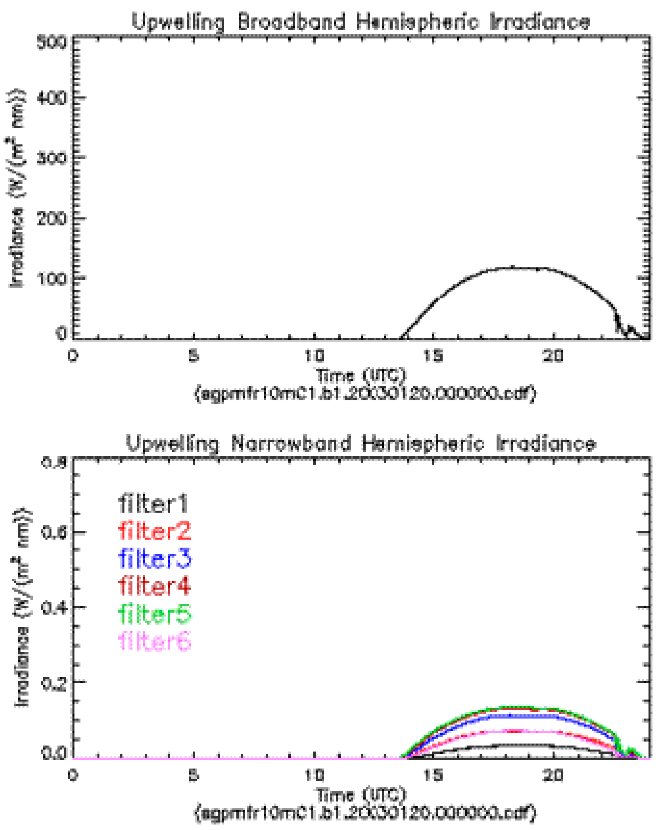

Figure 1.

5.3 User Notes and Known Problems

None to add at this time.

5.4 Frequently Asked Questions

Currently there is no FAQ for this instrument.

6. Data Quality

6.1 Data Quality Health and Status

The following links go to current data quality health and status results:

- DQ HandS (Data Quality [DQ] Health and Status)
- NCVweb for interactive data plotting using.

The tables and graphs shown contain the techniques used by ARM's DQ analysts, instrument mentors, and site scientists to monitor and diagnose DQ.

6.2 Data Reviews by Instrument Mentor

- **QC frequency**: Weekly
- **QC delay**: Up to one week
- **QC type**: Graphical plots
- **Inputs**: Raw and processed data
- **Outputs**: Summary reports
- **Reference**:

Once a week the instrument mentor downloads both the raw and processed (NetCDF) files from the ARM Data Archive. Time series plots of the NetCDF files for each instrument (every channel) are produced and examined. In addition, the raw data files are processed independently of the ARM Archive and compared to the NetCDF files from the archive for inconsistencies. Any problems found are reported so technicians can make the appropriate repairs. Once a month the mentor submits a report summarizing the general health and status of all the MFRs.

6.3 Data Assessments by Site Scientist/DQ Office

All DQ Office and most Site Scientist techniques for checking have been incorporated within DQ HandS and can be viewed there.

6.4 Value-Added Products and Quality Measurement Experiments

Currently there are no value-added products for this instrument.

7. Instrument Details

7.1 Detailed Description

7.1.1 List of Components

Many of the MFRSRs deployed at the SGP site have been manufactured by PNNL. The other MFRSRs are manufactured by Yankee Environmental Systems (Model MFR-6).

7.1.2 System Configuration and Measurement Methods

The MFR instrument is a MFRSR without the rotating shadowband. The sensors associated with each wavelength are all located in a small canister capped by a level, upward-looking, Lambertian diffuser. Radiation that strikes the diffuser is directed towards the sensors. These sensors consist of a single silicon photodetector for measuring broadband radiation, and a set of interference-filter-photodiode detectors for measuring spectral irradiances. Even though there is no shadowband, the instrument is configured to log data on the same interval as the MFRSR. A measurement is taken once every 20 seconds.

7.1.3 Specifications

The spectral irradiances are measured at or close to, the following wavelengths: 415, 500, 615, 673, 870 and 940 nm. These measurements are made over a passband of nominally 10 nm. A silicon photodiode measures broadband irradiances. These irradiances are reported in "counts" and are not calibrated per se, but rather linearly scaled to broadband instruments.

7.2 Theory of Operation

The MFR contains seven sensors. Six are interference-filter-photodiode detectors for measuring spectral irradiances, and one is a single silicon photodetector for measuring broadband radiation. The instrument is connected to a datalogger and measurements in mV are taken every 20 seconds.

7.3 Calibration

7.3.1 Theory

ARM employs two methods for calibrating MFRSRs. Primarily a standard lamp is used to produce calibration factors for the six narrowband channels. A secondary method, often used as a check of the lamp calibrations, is a set of Langley plots. Langley plots are used to extrapolate the values that would be read if the instrument was at the TOA. The TOA value, or I_0, is divided by the extraterrestrial spectrum to give a calibration factor for each channel. A lamp calibration of the MFR is straightforward. To perform a Langley calibration it would need to be configured with a rotating shadowband. Typically only lamp calibrations are performed on the MFR.

7.3.2 Procedures

To perform a standard lamp calibration, a MFRSR is placed in a calibration chamber and a lamp with a known spectral output is used. The known spectral distribution in (W m^{-2} nm^{-1}) is convolved with the output of each channel to produce calibration factors in (V W^{-1} m^{-2}). Langley plots can also be done for channels 415, 500, 615, 673 and 870 nm (channel 940 nm is a special case). On a clear day a Langley plot will give a stable I_0 for each channel when the data are extrapolated to the TOA. With several I_0s from clear days, an average I_0 for each channel is obtained. The average I_0 for each channel is divided by the extraterrestrial spectrum to give a calibration factor. Because water vapor is highly variable, the Langley method of calibrating is impractical for the 940-nm channel so only lamp calibrations are performed.

7.3.3 History

A detailed calibration history of all the ARM MFRs is too lengthy to be given here. To date, the instrument's calibration has been driven by instrument failure; that is, when either an instrument head or board fails, the offending component is replaced with a new one that has been freshly calibrated. This constitutes a "calibration" of the instrument. (This "calibration" procedure may change in the future.)

7.4 Operation and Maintenance

7.4.1 User Manual

Not available in electronic format at this time.

7.4.2 Routine and Corrective Maintenance Documentation

Time series plots are monitored to ensure the instrument is operating properly. Careful monitoring of the data can also interfere with filters that are failing.

7.4.3 Software Documentation

ARM netCDF file header descriptions may be found at MFRSR, MFR10M, and MFR25M Data Object Design Changes.

7.4.4 Additional Documentation

March 1998: The laboratory calibration of the instruments is problematic. By comparing the laboratory calibrations to an estimate of the calibrations obtained by a Langley analysis, it appears that some calibration factors can be in error by as much as 50%. The user of the MFRSR flux data should be aware that some of these data might not be very accurate.

November 1999: The laboratory calibrations of the MFRSR heads have significantly improved and are now being checked before field deployment by calibrations performed using the Langley method. This "pre-deployment" checking has resulted in a significant improvement in initial calibration accuracy; an estimate of this accuracy is plus or minus 4% (or maybe even a little better).
The maintenance procedures seem adequate, although some of the instruments are "out of alignment"; this lack of alignment can corrupt data taken during certain times of day.

7.5 Glossary

See the ARM Glossary.

7.6 Acronyms

ARM	Atmospheric Radiation Measurement (Program)
ASRC	Atmospheric Sciences Research Center
DQ	data quality

FWHM	full width at half maximum
MFR	multi-filter radiometer
MFRSR	multi-filter rotating shadowband radiometer
PNNL	Pacific Northwest National Laboratory
SGP	Southern Great Plains
TOA	top-of-atmosphere
TWP	Tropical Western Pacific

Also see the ARM Acronyms and Abbreviations.

7.7 Citable References

Goody, RM and YL Yung. 1989. *Atmospheric Radiation Theoretical Basis*. Oxford University Press, New York.

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