Global Hydrology Resource Center

Data User Guide

GPM Ground Validation Duke Microwave Radiometer (MWR) IPHEx

Introduction

The GPM Ground Validation Duke Microwave Radiometer (MWR) IPHEx dataset consists of data collected by the MWR, which is a sensitive microwave radiometer that detects the microwave radiances at two frequencies: 23.8 and 31.4 GHz. The measurements are are used to determine the presence of vapor and liquid water molecules in the atmosphere along with other derived parameters. These data were obtained during the Integrated Precipitation and Hydrology Experiment (IPHEx) field experiment, which was held in North Carolina with the goal to characterize warm season orographic precipitation regimes and the relationship between precipitation regimes and hydrologic processes in regions of complex terrain. These data are available for May 1, 2014 through June 15, 2014 and are in netCDF-3 format.

Citation

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Keywords:

Duke, GHRC, North Carolina, IPHEx, Microwave Radiometer, MWR, hail, hail intensity, infrared temperature, liquid water path, precipitable water vapor, rain, precipitation, rain intensity, pressure, relative humidity, temperature, wind direction, wind speed

Campaign

The Global Precipitation Measurement (GPM) mission Ground Validation campaign used a variety of methods for validation of GPM satellite constellation measurements prior to and after launch of the GPM Core Satellite, which launched on February 27, 2014. The instrument validation effort included numerous GPM-specific and joint agency/international external field campaigns, using state of the art cloud and precipitation observational infrastructure (polarimetric radars, profilers, rain gauges, and disdrometers). Surface rainfall was measured by very dense rain gauge and disdrometer networks at various field campaign sites. These field campaigns accounted for the majority of the effort and resources expended by GPM GV. More information about the GPM mission is available at https://pmm.nasa.gov/GPM/.

One of the GPM Ground Validation field campaigns was the Integrated Precipitation and Hydrology Experiment (IPHEx) which was held in North Carolina during 2013 and 2014 with an intensive observing period from May 1 to June 15, 2014. The goal of IPHEx was to characterize warm season orographic precipitation regimes and the relationship between precipitation regimes and hydrologic processes in regions of complex terrain. The IPHEx campaign was part of the development, evaluation, and improvement of remote-sensing precipitation algorithms in support of the GPM mission through NASA GPM Ground Validation field campaign (IPHEX_GVFC) and the evaluation of Quantitative Precipitation Estimation (QPE) products for hydrologic forecasting and water resource applications in the Upper Tennessee, Catawba-Santee, Yadkin-Pee Dee, and Savannah river basins (IPHEX-HAP, H4SE). NOAA Hydrometeorology Testbed (HTM) has synergy with this project. More information about IPHEx is available at https://pmm.nasa.gov/IPHEx.

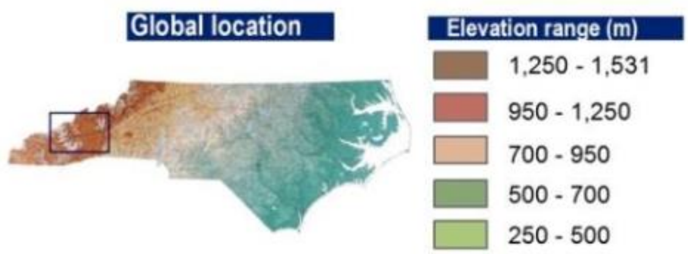

Figure 1: Region of North Carolina IPHEx campaign ground validation (image source: http://gpm-gv.gsfc.nasa.gov/Gauge/)

Instrument Description

The Microwave Radiometer (MWR) is a ground-based instrument used in the IPHEx field campaign. The MWR detects microwave emissions of the atmosphere at two or three frequencies. The measured radiances are sensitive to the presence of vapor and liquid water molecules in the atmosphere. Three MWRs were placed in the IPHEx study region that provided time-series measurements of brightness temperature, integrated water vapor, liquid water, and other derived products. During the IPHEx campaign, two 3-channel MWRs and one 2-channel MWR were used. The 3-channel MWRs measure frequencies of 23.834, 30.0, and 89.0 GHz, and 2-channel MWR measures frequencies of 23.8 and 31.4 GHz. Cloud liquid water in the atmosphere can be determined using brightness temperatures at the 31.4 GHz frequency channel, while water vapor can be determined by the 23.8 GHz frequency because of the relative sensitivities of the channels. Algorithms are also used to convert the brightness temperatures into hail, wind, and rain measurements.

The MWR uses a low power, low noise intermediate frequency (IF) amplifier. Figure 1 shows the MWR instrument on a ground station, while Figure 2 shows the MWR instrument with its cover removed. Table 1 describes the instrument specifications. More information about the MWR is available at https://www.arm.gov/publications/tech_reports/handbooks/mwr_handbook.pdf, https://www.arm.gov/publications/tech_reports/handbooks/mwr3c_handbook.pdf, and Westwater et al., 2001.

Figure 1: Microwave Radiometer (MWR) instruments. Left to right: MWR 2 channel, eastern MWR 3 channel, and inner region valley MWR 3 channel
(Image source: https://www.arm.gov/publications/programdocs/doe-sc-arm-16-008.pdf)

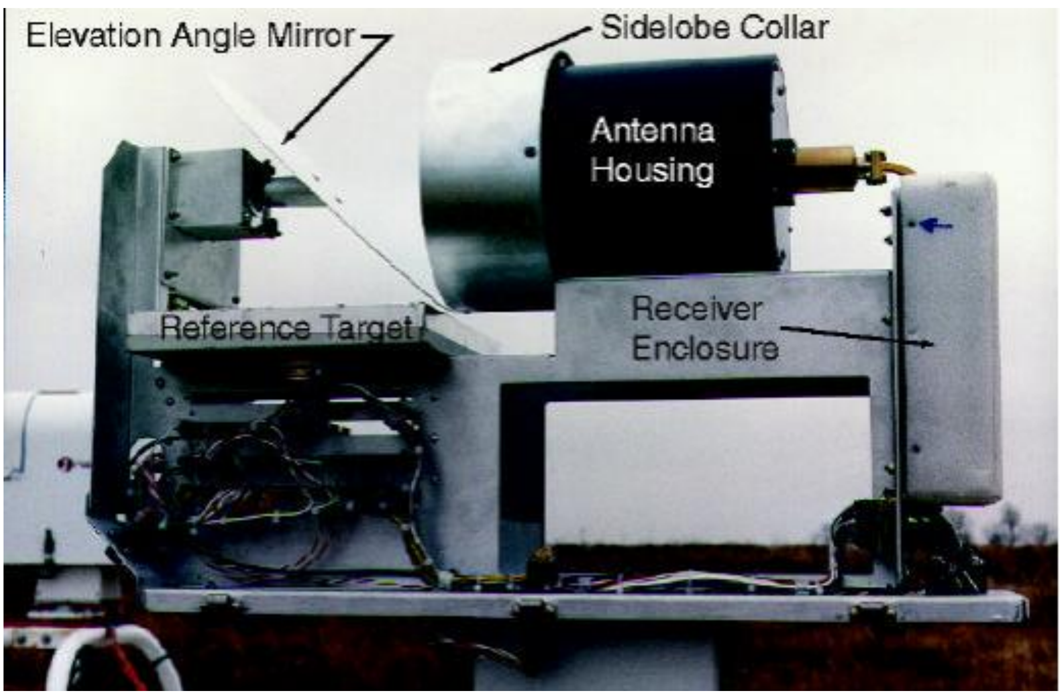

Figure 2: Microwave Radiometer (MWR) instrument with its cover removed
Photo credit: Liljegren, 1999

Table 1: Instrument Specifications

Parameter	Value
Sample Time	User selectable; 20 s in Line of Sight mode, 58 s in tipping mode
Accuracy	0.3 K
Resolution	0.25 K
Radiometric range	0 to 700 K
Operating range	-20 to +50°C
Angular coverage	All sky
Pointing slew rate	3°/second, azimuth; >90°/second, elevation
Field of view	5.9° at 23.4 GHz, 4.5° at 31.4 GHz (full width at half maximum)

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Data Characteristics

The GPM Ground Validation Duke Microwave Radiometer (MWR) IPHEx level 2 data are available in netCDF-3 format.

Table 2: Data Characteristics

Characteristic	Description
Platform	Ground station
Instrument	Microwave Radiometer (MWR)
Projection	n/a
Spatial Coverage	N: 35.80 , S: 35.52, E: -82.66, W: -83.09 (North Carolina)
Spatial Resolution	5.9 degrees to 4.5 degrees
Temporal Coverage	May 1, 2014 - June 15, 2014
Temporal Resolution	Daily
Sampling Frequency	~50 seconds
Parameters	Brightness temperatures and other derived parameters including hail intensity, infrared temperature, liquid water path, precipitable water vapor, rain intensity, pressure, relative humidity, temperature, wind direction, wind speed
Version	1
Processing Level	2

File Naming Convention

The GPM Ground Validation Duke Microwave Radiometer (MWR) IPHEx dataset has files with the naming convention shown below. The data files are available in netCDF-3 format.

Data files: iphex_oscmwr[3c|los|tip]S#.x1.YYYYMMDD.hhmmss.cdf

Table 3: File naming convention variables

Variable	Description
[3c|los|tip]	Type of data: 3c = identifies the 3 channel MWR files los = Line of Sight mode, 2 channel MWR file tip = tipping mode, 2 channel MWR file
S#	Site number: S1 = Maggie Valley, North Carolina (3 channel) S2 = AB Tech Madison, North Carolina (3 channel) S3 = Purchase Knob, South Carolina (2 channel)
x1	Data level: a1 = calibration factors applied and converted to geophysical units b1 = quality-control checks applied to at least one measurement and stored in an accompanying quality-control field meeting quality-control standards listed in the 'Quality Assessment' section below in Table 7.
YYYY	Four-digit year
MM	Two-digit month
DD	Two-digit day
hh	Two-digit hour in UTC
mm	Two-digit month in UTC
ss	Two-digit second in UTC
.cdf	netCDF-3 format

Data Parameters

Each data file contains multiple data fields. Table 4 shows information on the primary data fields within each iphex_oscmwr3cS#.x1.YYYYMMDD.hhmmss.cdf file, including quality controlled measurements. Table 5 and Table 6 shows information on data fields within the iphex_oscmwrtipS#.x1.YYYYMMDD.hhmmss.cdf files and iphex_oscmwrlosS#.x1.YYYYMMDD.hhmmss.cdf files, respectively. Values for these quality controlled measurements are described in Table 8.

Table 4: Data Fields for iphex_oscmwr3cS#.x1.YYYYMMDD.hhmmss.cdf files

Field Name	Description	Data Type	Unit
alt	Altitude above mean sea level	float	m
azimuth	Azimuth	float	degrees
base_time	Base time in Epoch	int	Seconds since 1970-1-1 0:00:00 0:00
elevation	Elevation	float	degrees
hail_accumulation	Hail accumulation	float	hit/cm^2
hail_duration	Hail duration	float	s
hail_intensity	Hail intensity	float	hit/(hr cm^2)
infrared_temperature	Zenith-pointing infrared temperature at 10 um	float	K
lat	North latitude (+ will be North, - will be South)	float	Degrees North
lon	East longitude (+ will be East, - will be West)	float	Degrees East
lwp	Liquid Water Path	float	mm
lwp_err	Estimated 1-sigma uncertainty in lwp	float	mm
pwv	Precipitable Water Vapor	float	cm
pwv_err	Estimated 1-sigma uncertainty in pwv	float	cm
qc_azimuth	Quality check results on azimuth field	int	-
qc-elevation	Quality check results on elevation	int	-
qc_hail_accumulation	Quality check results on hail accumulation	int	-
qc_hail_duration	Quality check results on hail duration	int	-
qc_hail_intensity	Quality check results on hail intensity	int	-
qc_infrared_temperature	Quality check results on zenith-pointing infrared temperature at 10 um	int	-
qc_rain_accumulation	Quality check results on rain accumulation	int	-
qc_rain_duration	Quality check results on rain duration	int	-
qc_rain_intensity	Quality check results on rain intensity	int	-
qc_rain_peak_intensity	Quality check results on rain peak intensity	int	-

qc_surface_pressure	Quality check results on Ambient surface pressure	int	-
qc_surface_relative_humidity	Quality check results on Ambient surface relative humidity	int	-
qc_surface_temperature	Quality check on Ambient surface temperature	int	-
qc_tbsky23	Quality check results on 23.834 GHz sky brightness temperature	int	-
qc_tbsky30	Quality check results on 30.0 GHz sky brightness temperature	int	-
qc_tbsky89	Quality check results on 89.0 GHz sky brightness temperature	int	-
qc_time	Quality check results on time offset from midnight	int	-
qc_wind_direction_avg	Quality check results on wind direction average	int	-
qc_wind_direction_max	Quality check results on wind direction maximum	int	-
qc_wind_direction_min	Quality check results on wind direction minimum	int	-
qc_wind_speed_avg	Quality check results on wind speed average	int	-
qc_wind_speed_max	Quality check results on wind speed maximum	int	-
qc_wind_speed_min	Quality check results on wind speed minimum	int	-
rain_accumulation	Rain accumulation	float	mm
rain_duration	Rain duration	float	s
rain_intensity	Rain intensity	float	mm/hr
rain_peak_intensity	Rain peak intensity	float	mm/hr
surface_pressure	Ambient surface pressure	float	kPa
surface_relative_humidity	Ambient surface relative humidity	float	%
surface_temperature	Ambient surface absolute temperature	float	Degrees C
tbsky23	23.834 GHz sky brightness temperature	float	K
tbsky30	30.0 GHz sky brightness temperature	float	K
tbsky89	89.0 GHz sky brightness temperature	float	K
time	Time offset from midnight	double	Seconds since YYYY-MM-DD 00:00:00 0:00
time_offset	Time offset from base_time	double	Seconds since YYYY-MM-DD

			00:00:00 0:00
wind_direction_avg	Wind direction average	float	degrees
wind_direction_max	Wind direction maximum	float	degrees
wind_direction_min	Wind direction minimum	float	degrees
wind_speed_avg	Wind speed average	float	m/s
wind_speed_max	Wind speed maximum	float	m/s
wind_speed_min	Wind speed minimum	float	m/s

Table 5: Data Fields for iphex_oscmwrtipS#.x1.YYYYMMDD.hhmmss.cdf files

Field Name	Description	Data Type	Unit
actaz	Actual azimuth	float	degrees
actel	Actual elevation angle	float	degrees
alt	Altitude above mean sea level	float	m
base_time	Base time in Epoch	int	Seconds since 1970-1-1 0:00:00 0:00
bb23	23.8 GHz blackbody signal	float	count
bb31	31.4 GHz blackbody signal	float	count
bbn23	23.8 GHz blackbody + noise injection signal	float	count
bbn31	31.4 GHz blackbody + noise injection signal	float	count
lat	North latitude (+ will be North, - will be South)	float	Degrees North
liqtip	Total liquid water along zenith path using tip-derived brightness temperatures	float	cm
lon	East longitude (+ will be East, - will be West)	float	Degrees East
r23	23.8 GHz goodness-of-fit coefficient	float	-
r31	31.4 GHz goodness-of-fit coefficient	float	-
tbsky23tip	23.8 GHz sky brightness temperature derived from tip curve	float	K
tbsky31tip	31.4 GHz sky brightness temperature derived from tip curve	float	K
tc23	Temperature correction coefficient at 23.8 GHz	float	-
tc31	Temperature correction coefficient at 31.4 GHz	float	-
time	Time offset from midnight	double	Seconds since YYYY-MM-DD 00:00:00 0:00
time_offset	Time offset from base_time	double	Seconds since YYYY-MM-DD 00:00:00 0:00
tip_angles	Tip angles used for each tip curve	float	degrees

tipsky23	23.8 GHz sky signal	float	count
tipsky31	31.4 GHz sky signal	float	count
tkair	Ambient temperature	float	K
tkbb	Blackbody kinetic temperature	float	K
tknd	Noise diode mount temperature	float	K
tkxc	Mixer kinetic (physical) temperature	float	K
tnd23	Noise injection temperature at 23.8 GHz adjusted to tkbb	float	K
tnd23I	Noise injection temperature at 23.8 GHz derived from this tip	float	K
tnd31	Noise injection temperature at 31.4 GHz adjusted to tkbb	float	K
tnd31I	Noise injection temperature at 31.4 GHz derived from this tip	float	K
tnd_nom23	Noise injection temperature at nominal temperature at 23.8 GHz	float	K
tnd_nom31	Noise injection temperature at nominal temperature at 31.4 GHz	float	K
vaptip	Total water vapor along zenith path using tip-derived brightness temperatures	float	cm
wet_window	Water on Teflon window (1 = wet, 0 = dry)	float	-

Table 6: Data Fields for iphex_oscmwrlosS#.x1.YYYYMMDD.hhmmss.cdf files

Field Name	Description	Data Type	Unit
alt	Altitude above mean sea level	float	m
base_time	Base time in Epoch	int	Seconds since 1970-1-1 0:00:00 0:00
bb23	23.8 GHz blackbody signal	float	count
bb31	31.4 GHz blackbody signal	float	count
bbn23	23.8 GHz blackbody + noise injection signal	float	count
bbn31	31.4 GHz blackbody + noise injection signal	float	count
lat	North latitude (+ will be North, - will be South)	float	Degrees North
liq	Total liquid water along LOS path	float	cm
lon	East longitude (+ will be East, - will be West)	float	Degrees East
qc_bb23	Quality check results on field: 23.8 GHz blackbody signal	int	-
qc_bb31	Quality check results on field: 31.4 GHz blackbody signal	int	-
qc_bbn23	Quality check results on field: 23.8 GHz blackbody + noise injection signal	int	-

qc_bbn31	Quality check results on field: 31.4 GHz blackbody + noise injection signal	int	-
qc_liq	Quality check results on field: Total liquid water along LOS path	int	-
qc_sky23	Quality check results on field: 23.8 sky signal	int	-
qc_sky31	Quality check results on field: 31.4 GHz sky signal	int	-
qc_tbsky23	Quality check results on field: 23.8 GHz sky brightness temperature	int	-
qc_tbsky31	Quality check results on field: 31.4 GHz sky brightness temperature	int	-
qc_time	Quality check results on field: Time offset from midnight	int	-
qc_tkair	Quality check results on field: Ambient temperature	int	-
qc_tkbb	Quality check results on field: blackbody kinetic temperature	int	-
qc_tknd	Quality check results on field: Noise diode mount temperature	int	-
qc_tkxc	Quality check results on field: Mixer kinetic(physical) temperature	int	-
qc_vap	Quality check results on field: Total water vapor along LOS path	int	-
sky23	23.8 GHz sky signal	float	count
sky31	31.4 GHz sky signal	float	count
tbsky23	23.8 GHz sky brightness temperature	float	K
tbsky31	31.4 GHz sky brightness temperature	float	K
tc23	Temperature correction coefficient at 23.8 GHz	float	K/K
tc31	Temperature correction coefficient at 31.4 GHz	float	K/K
time	Time offset from midnight	double	Seconds since YYYY-MM-DD 00:00:00 0:00
time_offset	Time offset from base_time	double	Seconds since YYYY-MM-DD 00:00:00 0:00
tkair	Ambient temperature	float	K
tkbb	Blackbody kinetic temperature	float	K
tknd	Noise diode mount temperature	float	K
tkxc	Mixer kinetic (physical) temperature	float	K
tnd23	Noise injection temperature at 23.8 GHz adjusted to tkbb	float	K
tnd31	Noise injection temperature at 31.4 GHz adjusted to tkbb	float	K
tnd_nom23	Noise injection temperature at nominal temperature at 23.8 GHz	float	K

tnd_nom31	Noise injection temperature at nominal temperature at 31.4 GHz	float	K
vap	Total water vapor along LOS path	float	cm
wet_window	Water on Teflon window (1 = wet, 0 = dry)	float	-

Algorithm

The calibrated noise diode is automatically used when brightness temperature is measured to inject a known temperature into the antenna waveguide. This will determine gain, as well as the offset, eliminating error due to any drift in the microwave radiometer. However, this gain is very sensitive to the temperature of the radiometer components, such as the feed horn, mixer, waveguides, etc. Because of this, the thermal stability of the instrument is directly related to stability of the gain. A set of scanning observations and measurements of an internal blackbody target and a noise diode is used to calibrate the MWR in a method called the "tip cal method". Algorithms with brightness temperature or radiance measurements as inputs are used to collect hail, wind, and rain measurements. More information regarding algorithms used to calibrate the instrument are available at https://www.arm.gov/publications/tech_reports/handbooks/mwr_handbook.pdf, https://www.osti.gov/scitech/servlets/purl/1253898, https://www.arm.gov/publications/tech_reports/handbooks/mwr3c_handbook.pdf, Westwater et al., 2001, and Liljegren, 1999.

Quality Assessment

Each file contains quality controlled measurements of radiance, which are described in Table 4 and Table 6. Table 7 shows the levels of uncertainty for instrument measurements. Values for the quality flags used are described in Table 8, with Table 9 defining the minimum and maximum thresholds for quality control for liquid water, water vapor, brightness temperature, and temperature. Table 10 defines time quality flags, and Table 11 specifies the qc_time limits used. More information about the quality assessment and other issues with these data are available in https://www.arm.gov/publications/tech_reports/handbooks/mwr_handbook.pdf and https://www.arm.gov/publications/tech_reports/handbooks/mwr3c_handbook.pdf.

Table 7: Measurement Uncertainties

Measurement	Uncertainty
Sky	0.018 K
Blackbody	0.12 K
Blackbody + Noise	~0.15 K
Gain Reference	~0.02 K
Receiver Gain	~0.09 K
Receiver Offset	0.035 K

Table 8: Data Quality Flags

Value	Definition
0	All QC checks passed
1	Sample contained ‘missing data’ value
2	Sample was less than prescribed minimum value
3	Sample failed both ‘missing data’ and minimum value checks
4	Sample greater than prescribed maximum value
5	Sample failed both minimum and maximum value checks (highly unlikely)
7	Sample failed minimum, maximum, and missing value checks (highly unlikely)
8	Sample failed delta check (change between this sample and precious sample exceeds a prescribed value)
9	Sample failed delta and missing data checks
10	Sample failed minimum and delta checks
11	Sample failed minimum, delta, and missing value checks
12	Sample failed maximum and delta checks
14	Sample failed minimum, maximum, and delta checks
15	Sample failed minimum, maximum, delta, and missing value checks

Table 9: Data Quality Thresholds

Field Name	Units	Min	Max	Delta
tknd	K	303	333	-
tkxc	K	303	333	0.5
tkbb	K	250	320	1
tkair	K	253	323	-
tnd23	K	163	353	-
bb23	counts	0	-	-
bbn23	counts	0	-	-
sky23	counts	0	-	-
tbsky23	K	2.73	100	0.01
tbsky30	K	2.73	330	-
tbsky89	K	2.73	330	-
tnd31	K	163	353	-
bb31	counts	0	-	-
bbn31	counts	0	-	-
sky31	counts	0	-	-
tbsky31	K	2.73	100	0.01
vap	cm	0	-	-
liq	cm	-3*rms *(*)*	-	-
sky_ir_temp	K	213	313	50
surface_pressure	kPa	70	110	-

surface_relative_humidity	%	0	110	-
surface_temperature	Deg C	-50	50	-
wet_window	-	1 *(**)*	-	-
tnd_nom23	K	163	353	80
tnd_nom31	K	163	353	80
tc23	K/K	-	-	-
tc31	K/K	-	-	-
wind_direction_avg	degrees	0	360	-
wind_direction_max	degrees	0	360	-
wind_direction_min	degrees	0	360	-
wind_speed_avg	m/s	0	30	-
wind_speed_max	m/s	0	30	-
wind_speed_min	m/s	0	30	-
infrared_temperature	K	173	305	-
rain_accumulation	mm	0	30	-
rain_duration	s	0	21,600	-
rain_intensity	mm/hr	0	500	-
hail_accumulation	hit/cm^2	0	10	-
hail_duration	s	0	3,600	-
hail_intensity	hit/(hr cm^2)	0	500	-
rain_peak_intensity	mm/hr	0	30	-

(*) rms is liquid_retrieval_rms_accuracy
(**) A value of 1 for the wet_window field means that the heater was ON at the time the sample was taken

Table 10: Time Quality Flags

Value	Description
0	Dt is within specified range
1	Dt is 0, duplicate sample
2	Dt is less than specified lower limit
4	Dt is greater than specified upper limit

Table 11: Limits for Time

Datastream	Lower Limit	Upper Limit
mwrlos	20	39

Software

No special software is required to read these netCDF-3 data files; however, software for reading netCDF, such as Panoply can be used to explore and view the data in the files.

Known Issues or Missing Data

During preventative maintenance, such as water used to clean the teflon window, positive "spikes" are produced in the measurements. It should also be noted that a curious bear damaged the 2 channel MWR twice while taking measurements. There were also issues with malfunctioning equipment causing periods of missing data. More information regarding known issues within these data are available in https://www.arm.gov/publications/tech_reports/handbooks/mwr_handbook.pdf and https://www.arm.gov/publications/programdocs/doe-sc-arm-16-008.pdf.

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