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Ka-Band ARM Zenith Radar (KAZR) Active Remote Sensing of Clouds (ARSCL) CloudSat Calibration (KAZRARSCL-CLOUDSAT) Value-Added Product Report

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February 2022

ARM

DISCLAIMER

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Acronyms and Abbreviations

ARM	Atmospheric Radiation Measurement
ARSCL	Active Remote Sensing of Clouds Value-Added Product
AWR	ARM West Antarctica Radiation Experiment (AWARE)
CFADS	contour frequency by altitude diagrams
CPR	CloudSat 95-GHz Cloud-Profiling Radar
DOD	Data Object Design
DQR	Data Quality Report
KAZR	Ka-Band ARM Zenith Radar
KAZRARSCL	Ka-Band ARM Zenith Radar-Active Remote Sensing of Clouds Value-Added Product
KAZRARSCL-CLOUDSAT	Ka-Band ARM Zenith Radar Active Remote Sensing of Clouds-CloudSat Calibration Value-Added Product
MDS	minimum detectable signal
MMCR	millimeter wavelength cloud radar
NASA	National Aeronautics and Space Administration
netCDF	Network Common Data Form
NSA	North Slope of Alaska
OLI	Oliktok Point
PR	Precipitation operating mode
RMSE	root-mean-square error
SGP	Southern Great Plains
SNR	signal-to-noise ratio
VAP	value-added product
WACR	W-Band ARM Cloud Radar

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1.0 Introduction

The Ka-band ARM Zenith Radar Active Remote Sensing of CLouds CloudSat-aligned (KAZRARSCL-CLOUDSAT) Value-Added Product (VAP) applies satellite-based reflectivity calibrations to KAZRARSCL data sets. The Atmospheric Radiation Measurement (ARM) user facility has primarily used radar subsystem calibration monitoring to track cloud radar reflectivity drift over time, since reliable external calibration sources or other absolute references (such as corner reflectors) have historically been unavailable or impracticable. A study by Kollias et al. (2019) examined cloud reflectivity profiles observed with a well-characterized spaceborne downward-pointing millimeter cloud radar, operating as part of NASA's CloudSat satellite mission (Tanelli et al. 2008). The Kollias team derived monthly statistical reflectivity offsets between CloudSat and the various generations of ARM cloud radars (millimeter wavelength cloud radar [MMCR], W-Band ARM Cloud Radar [WACR[, and Ka-band ARM Zenith Radar [KAZR]) for many, but not all, months at most fixed and mobile ARM sites over the period 2007-2017. These offsets, when available, are applied to the existing KAZRARSCL VAP products using the KAZRARSCL-CLOUDSAT VAP.

2.0 Algorithm and Methodology

The VAP creates a daily output product when the input KAZRARSCL product exists with valid cloud radar observations and there exists a CloudSat-based reflectivity offset for each KAZR operating radar mode for the day. If both requirements are not met, no output is produced for the day.

Once it is determined that the VAP can be run, the application of CloudSat reflectivity offsets to KAZRARSCL reflectivity is straightforward. The main requirement is that the appropriate reflectivity offset is added to each ARSCL reflectivity point in time and height. CloudSat offsets are provided at a monthly time interval, each representing six months of averaged reflectivity comparisons. The KAZR uses multiple radar operating modes to provide maximum radar sensitivity as well as spatial coverage. Radar moments (reflectivity, mean Doppler velocity, spectral width) are provided for each operating mode. The KAZRARSCL product optimally merges the operating modes, selecting the best mode for each time-height point, to provide best-estimate moments. KAZRARSCL provides a radar mode flag that indicates which mode was used in the merged fields at each time-height grid point. CloudSat reflectivity offsets for KAZR are also available for the individual operating modes.

The KAZRARSCL-CLOUDSAT VAP uses the KAZRARSCL radar mode flag to determine which CloudSat reflectivity offset is to be applied at each time-height point. Then the appropriate reflectivity offset value is added to each time-height point of the KAZRARSCL reflectivity and best-estimate reflectivity field. These modified fields are output to the KAZRARSCL-CLOUDSAT output datastream. The KAZRARSCL-CLOUDSAT product includes all fields from the input KAZRARSCL product, plus the CloudSat offsets (for all available operating modes) that were applied. Note that since only one CloudSat offset value is provided for each radar mode per month, only a single offset (per operating mode) is used and included in each daily KAZRARSCL-CLOUDSAT file. The VAP also reports the number of CloudSat-ARM radar samples used in determining the offset and the root-mean-squared error (RMSE) of the statistically derived offset, as reported in Kollias et al. (2019).

Appendix A provides a brief description of the method used to derive the CloudSat reflectivity offsets as well as the times and sites for which they are available.

2.1 Flow Chart

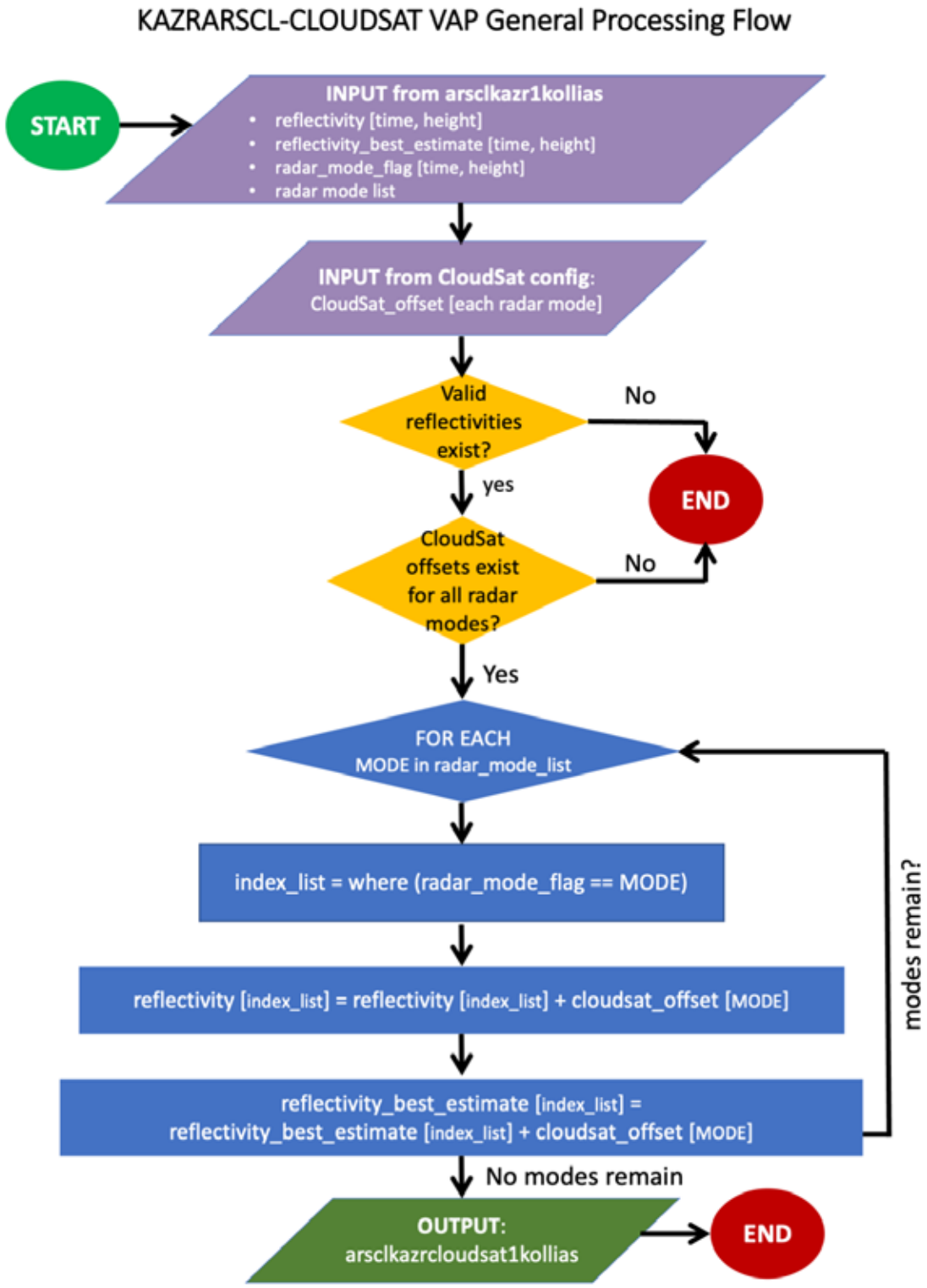

Figure 1. Processing flowchart for the KAZRARSCL-CLOUDSAT VAP.

3.0 Input Data

This product accepts the KAZRARSCL VAP full output datastream (as opposed to the smaller KAZRARSCL datastream that contains only cloud boundaries) as input along with CloudSat reflectivity offset values, which vary on a monthly basis.

All KAZRARSCL VAP variables are passed through to the KAZRARSCL-CLOUDSAT output file. Table 1 lists only those variables directly referenced within the VAP algorithm.

Table 1. Input datastream and variables used.

Radar / Input Datastream (highest data level available)	**Input Variable Name**	**Variable Long Name**
KAZR / arsclkazr1kollias (either data level .c0 or .c1)	reflectivity	Reflectivity
	reflectivity_best_estimate	Best-estimate reflectivity
	radar_mode_flag	Radar mode flag

CloudSat reflectivity offsets are input from a netCDF configuration file. The configuration files were created by reformatting a Matlab '.mat' file provided by Pavlos Kollias and Bernat Puigdomènech. The algorithm used to create these offsets is described in Kollias et al. (2019) and is summarized in Appendix A. The configuration files provide monthly reflectivity offsets, each of which represent a six-month time window of matched CloudSat and ARM radar observations.

4.0 Output Data

The VAP creates a daily netCDF file. Table 2 lists the major output variables for the KAZRARSCL VAP. Appendix B provides a full Data Object Design (DOD) for the output datastream.

Table 2. Major output variables for the arsclkazrcloudsat.c1 data set.

Variable Name	**Long Name**
reflectivity_best_estimate	Best-estimate reflectivity
reflectivity	Reflectivity
mean_doppler_velocity	Mean Doppler velocity
spectral_width	Spectral width
linear_depolarization_ratio	Linear depolarization ratio
reflectivity_clutter_flag	Reflectivity clutter flag
cloudsat_reflectivity_offset_applied	Statistically-derived reflectivity offset between KAZR and CloudSat
cloudsat_rmse	Root mean square error of statistically-derived reflectivity offset between KAZR and CloudSat

Variable Name	Long Name
cloudsat_num_samples	Number of available CloudSat and KAZR samples used to estimate reflectivity offset
radar_first_top	KAZR top height of lowest significant detection layer, before clutter removal
mean_doppler_velocity_dealias_flag	Indication of whether or not dealiasing was performed on the mean_doppler_velocity
radar_mode_flag	Radar mode flag

4.1 Sites and Time Periods for which the VAP is Available

The ARSCL-CLOUDSAT VAP has been processed for the following sites and time periods. These are the locations and times for which all needed inputs are available.

Table 3. KAZRARSCL-CLOUDSAT VAP site and time period availability.

ARM Site	Radar	Time Period
NSA	KAZR	2012.03.01-2013.01.31 2013.05.01-2015.06.30 2016.01.01-2016.12.31 2017.03.01-2017.06.30
SGP	KAZR	2012.03.01-2012.07.31 2012.09.01-2013.06.30 2014.01.01-2014.02.28 2014.04.01-2015.01.31 2015.09.01-2015.11.30 2016.06.01-2017.08.31
AWR	KAZR	2016.04.01-2016.05.31 2016.08.01-2016.12.31
OLI	KAZR	2015.11.01-2017.11.29

4.2 Quicklooks

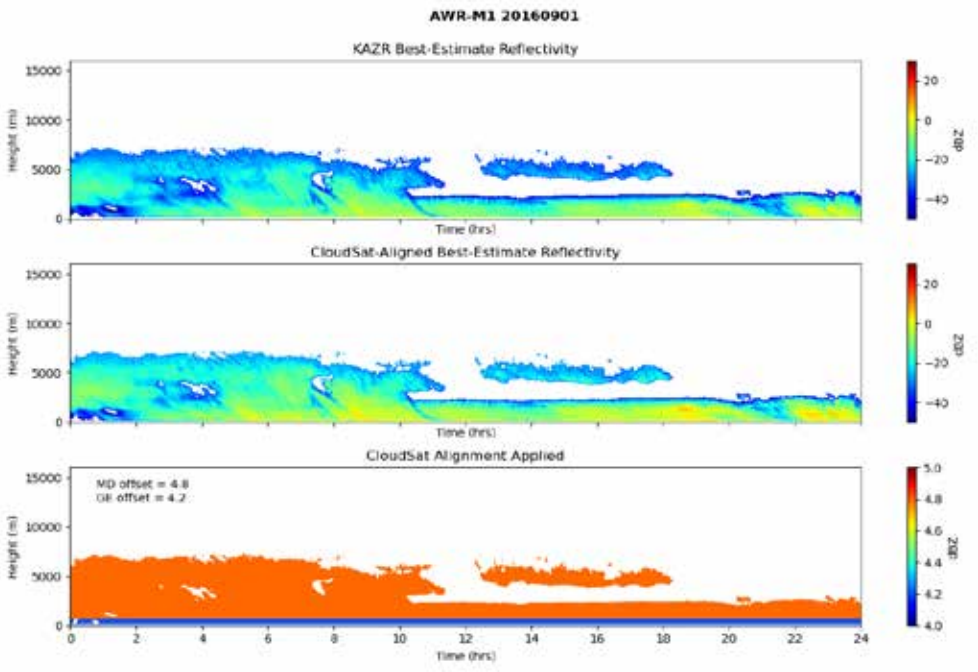

Figure 2. Quicklook image created by the KAZRARSCL-CLOUDSAT VAP for the AWR.M1 site on 20160901. The top image is KAZRARSCL reflectivity_best_estimate. The middle is the same field after the appropriate CloudSat reflectivity offsets have been applied. The bottom image shows the CloudSat offset that was applied at each time-height point based on the KAZR mode in use.

4.3 Frequently Asked Questions

Why are there dates with no output files?

a. No output is produced for this product when the cloud radar observations are not available or are identified to be 'bad' in the KAZRARSCL input product for the entire day.

b. No output is produced for this product if no CloudSat reflectivity offset is available for one or more of the radar operating modes in use. An exception to this rule is the Oliktok Point (OLI) site. Here the decision was made to produce the product even though there are no CloudSat offsets available for the Precipitation (PR) operating mode. A Data Quality Report (DQR) has been issued to notify users.

5.0 Summary

The KAZRARSCL-CLOUDSAT VAP applies reflectivity offsets to ARM's KAZR radars to align their reflectivities more closely with those observed by the well-characterized 95-GHz Cloud-Profiling Radar (CPR) of the NASA CloudSat satellite mission. The algorithm used to determine the reflectivity offsets is described in Kollias et al. (2019). It is important to note that the approach used is statistical and is not necessarily instantaneously representative of the reflectivity offset and/or drift for a singular event in the record. Currently the VAP is has been processed only for KAZR-based ARSCL data.

6.0 References

Kollias, P, B Puigdomènech Treserras, and A Protat. 2019. "Calibration of the 2007–2017 record of ARM Cloud Radar Observations using CloudSat." *Atmospheric Measurement Techniques* 12(9): 4949

Appendix A

Determination of CloudSat Reflectivity Offsets

The reflectivity offsets applied by this VAP resulted from the study described in Kollias et al. (2019) that examines cloud reflectivity profiles observed with a spaceborne downward-pointing millimeter cloud radar, operating as part of NASA's CloudSat satellite mission. The CloudSat 95-GHz Cloud-Profiling Radar, or CPR (Tanelli et al., 2008), has been well characterized and provides a reliable source of downward-looking reflectivity profiles along its polar-orbiting path.

CloudSat reflectivity profiles were compared with those observed by zenith-pointing 35- and 95-GHz ARM cloud radars at numerous fixed and mobile ARM sites. CloudSat profiles were included in the calibration algorithm when they fell within a 200-300 km radius of an ARM site. (Note: this radius of influence implies this monitoring approach is statistical, and as with most relative offset monitoring, is not necessarily instantaneously representative of the reflectivity offset and/or drift for any singular event in the record.) CloudSat observations below 500 m above the Earth's surface are omitted, due to excessive ground clutter, as are observations with low signal-to-noise ratio (SNR; CPR Cloud mask < 20) and poor data quality. Freezing level was extracted from the 2C-PRECIP-COLUMN product.

ARM radar observations were used only when they fell within a two-hour time window centered on a CloudSat overpass. Radar observations having SNR < -15 dB are omitted. Reflectivities are corrected for gaseous attenuation in a consistent fashion for both radar platforms; the correction includes appropriate adjustments when radar frequencies differ. Adjustments are also made to account for ice crystal scattering differences when CloudSat and ARM radar frequencies differ. In order to match CloudSat temporal and vertical resolutions, ARM observations are averaged to 1-minute time samples at 250 m vertical resolution.

For overpasses having appropriate observations from both the CPR and ARM radars, both data sets are prepared as follows: (a) Only 'non-precipitating' radar profiles are retained (see Kollias et al. for further details) to ensure minimal hydrometeor attenuation (b) The more sensitive ARM radar observations are degraded by omitting returns having minimum detectable signal (MDS) less than approximately -30 dBZ (which is the approximate CloudSat radar MDS).

At this point, the original ARM reflectivities are offset by values ranging from -15 to +15 dBZ, in intervals of 0.1 dB, creating 301 separate data sets. In each of these offset data sets, ARM Ka-band reflectivities (for MMCR or KAZR) are converted to their corresponding 95-GHz values to match the CPR For each offset data set, all remaining profiles within a six-month time window are represented as Contour Frequency by Altitude Diagrams (CFADs) and then converted to mean reflectivity height profiles. Finally, the reflectivity offset having the lowest RMSE becomes the month's calibration offset. Note that the month associated with offset is the first month in the six-month time window used in deriving it.

Appendix B

Data Object Design of arsclkarzcloudsat.c1

class: arsclkazrcloudsat
level: c1
version: 1.1

time = UNLIMITED
height = 596
layer = 10
radar_mode = 4
string_len = 2

base_time():int
  string
  long_name = Base time in Epoch
  units = seconds since 1970-1-1 0:00:00 0:00
  ancillary_variables = time_offset

time_offset(time):double
  long_name = Time offset from base_time
  units
  ancillary_variables = base_time

time(time):double
  long_name = Time offset from midnight
  units
  standard_name = time

height(height):float
  long_name = Height above ground level
  units = m
  standard_name = height

layer(layer):int
  long_name = Cloud layer number
  units = 1

radar_mode(radar_mode, string_len):char
long_name = Radar mode names
units = 1
comment = Only two radar modes are in use simultaneously. See global attribute radar_modes_in_use for list of modes used

reflectivity_best_estimate(time, height):float*
long_name = Best-estimate reflectivity statistically aligned with CloudSat
units = dBZ
ancillary_variables = qc_reflectivity_best_estimate cloudsat_reflectivity_offset_applied
valid_min:float = -90
valid_max:float = 50
missing_value:float = -9999
resolution:float = 0.001
comment = Contains data from best radar operating mode (see radar_mode_flag); data points with non-missing values contain hydrometeors or both hydrometeors and clutter (see reflectivity_clutter_flag)
_DeflateLevel:int = 3
_ChunkSizes:int
_Shuffle = false
standard_name = equivalent_reflectivity_factor

qc_reflectivity_best_estimate(time, height):int
long_name = Quality check results on variable: Best-estimate reflectivity statistically aligned with CloudSat
units = 1
description = This variable contains bit-packed integer values, where each bit represents a QC test on the data. Non-zero bits indicate the QC condition given in the description for those bits; a value of 0 (no bits set) indicates the data has not failed any QC tests.
flag_method = bit
bit_1_description = Value is less than the valid_min.
bit_1_assessment = Bad
bit_2_description = Value is greater than the valid_max.
bit_2_assessment = Bad
bit_3_description = Data value not available in input file, data value has been set to missing_value.
bit_3_assessment = Bad
_DeflateLevel:int = 2
_ChunkSizes:int
_Shuffle = false
standard_name = quality_flag

reflectivity(time, height):float*
long_name = Reflectivity statistically aligned with CloudSat
units = dBZ
ancillary_variables = qc_reflectivity cloudsat_reflectivity_offset_applied
valid_min:float = -90

valid_max:float = 50
missing_value:float = -9999
resolution:float = 0.001
comment = Contains data from best radar operating mode (see radar_mode_flag); Data points with non-missing values had significant power detections from hydrometeors and/or clutter
_DeflateLevel:int = 2
_ChunkSizes:int
_Shuffle = false
standard_name = equivalent_reflectivity_factor

qc_reflectivity(time, height):int
long_name = Quality check results on variable: Reflectivity statistically aligned with CloudSat
units = 1
description = This variable contains bit-packed integer values, where each bit represents a QC test on the data. Non-zero bits indicate the QC condition given in the description for those bits; a value of 0 (no bits set) indicates the data has not failed any QC tests.
flag_method = bit
bit_1_description = Value is less than the valid_min.
bit_1_assessment = Bad
bit_2_description = Value is greater than the valid_max.
bit_2_assessment = Bad
bit_3_description = Data value not available in input file, data value has been set to missing_value.
bit_3_assessment = Bad
_DeflateLevel:int = 2
_ChunkSizes:int
_Shuffle = false
standard_name = quality_flag

mean_doppler_velocity(time, height):float*
long_name = Mean Doppler velocity
units = m/s
ancillary_variables = qc_mean_doppler_velocity
valid_min:float = -25
valid_max:float = 25
missing_value:float = -9999
resolution:float = 0.001
positive = up
comment = Contains data from best radar operating mode (see radar_mode_flag); Data points with non-missing values had significant power detections from hydrometeors and/or clutter
_DeflateLevel:int = 2
_ChunkSizes:int
_Shuffle = false
standard_name = radial_velocity_of_scatterers_away_from_instrument

qc_mean_doppler_velocity(time, height):int
long_name = Quality check results on variable: Mean Doppler velocity

units = 1
description = This variable contains bit-packed integer values, where each bit represents a QC test on the data. Non-zero bits indicate the QC condition given in the description for those bits; a value of 0 (no bits set) indicates the data has not failed any QC tests.
flag_method = bit
bit_1_description = Value is less than the valid_min.
bit_1_assessment = Bad
bit_2_description = Value is greater than the valid_max.
bit_2_assessment = Bad
bit_3_description = Data value not available in input file, data value has been set to missing_value.
bit_3_assessment = Bad
_DeflateLevel:int = 2
_ChunkSizes:int
_Shuffle = false
standard_name = quality_flag

spectral_width(time, height):float*
long_name = Spectral width
units = m/s
ancillary_variables = qc_spectral_width
valid_min:float = 0
valid_max:float = 10
missing_value:float = -9999
resolution:float = 0.001
comment = Contains data from best radar operating mode (see radar_mode_flag); Data points with non-missing values had significant power detections from hydrometeors and/or clutter
_DeflateLevel:int = 1
_ChunkSizes:int
_Shuffle = false
standard_name = radar_doppler_spectrum_width

qc_spectral_width(time, height):int
long_name = Quality check results on variable: Spectral width
units = 1
description = This variable contains bit-packed integer values, where each bit represents a QC test on the data. Non-zero bits indicate the QC condition given in the description for those bits; a value of 0 (no bits set) indicates the data has not failed any QC tests.
flag_method = bit
bit_1_description = Value is less than the valid_min.
bit_1_assessment = Bad
bit_2_description = Value is greater than the valid_max.
bit_2_assessment = Bad
bit_3_description = Data value not available in input file, data value has been set to missing_value.
bit_3_assessment = Bad
_DeflateLevel:int = 2
_ChunkSizes:int

_Shuffle = false
standard_name = quality_flag

linear_depolarization_ratio(time, height):float*
long_name = Linear depolarization ratio
units = dBZ
ancillary_variables = qc_linear_depolarization_ratio
missing_value:float = -9999
valid_min:float = -50
valid_max:float = 50
comment = Contains data from best radar operating mode (see radar_mode_flag); Data points with non-missing values had significant power detections from hydrometeors and/or clutter
_DeflateLevel:int = 2
_ChunkSizes:int
_Shuffle = false
standard_name = radar_linear_depolarization_ratio

qc_linear_depolarization_ratio(time, height):int
long_name = Quality check results on variable: Linear depolarization ratio
units = 1
description = This variable contains bit-packed integer values, where each bit represents a QC test on the data. Non-zero bits indicate the QC condition given in the description for those bits; a value of 0 (no bits set) indicates the data has not failed any QC tests.
flag_method = bit
bit_1_description = Value is less than the valid_min.
bit_1_assessment = Bad
bit_2_description = Value is greater than the valid_max.
bit_2_assessment = Bad
bit_3_description = Data value not available in input file, data value has been set to missing_value.
bit_3_assessment = Bad
_DeflateLevel:int = 1
_ChunkSizes:int
_Shuffle = false
standard_name = quality_flag

signal_to_noise_ratio(time, height):float
long_name = Signal-to-noise ratio
units = dB
missing_value:float = -9999
resolution:float = 0.001
comment = Contains data from best radar operating mode (see radar_mode_flag); Data points with non-missing values had significant power detections from hydrometeors and/or clutter
_DeflateLevel:int = 2
_ChunkSizes:int
_Shuffle = false

reflectivity_clutter_flag(time, height):short
long_name = Reflectivity clutter flag
units = 1
flag_values:short = 0, 1, 2, 3, 9, 10
flag_meanings = No_significant_detection Hydrometeor-only_detection
Both_hydrometeor_and_clutter_detection Clutter-only_detection Bad_data Missing_data
flag_0_description = No significant detection
flag_1_description = Hydrometeor-only detection
flag_2_description = Both hydrometeor and clutter detection
flag_3_description = Clutter-only detection
flag_9_description = Bad data
flag_10_description = Missing data
_DeflateLevel:int = 2
_ChunkSizes:int
_Shuffle = false

cloudsat_reflectivity_offset_applied(radar_mode):float
long_name = Statistically-derived reflectivity offset between KAZR and CloudSat
units = dBZ
aancillary_variables = cloudsat_rmse cloudsat_num_samples
missing_value:float = -9999.

cloudsat_rmse(radar_mode):float
long_name = Root mean square error of statistically-derived reflectivity offset between KAZR and
CloudSat
units = dBZ
missing_value:float = -9999.

cloudsat_num_samples(radar_mode):int
long_name = Number of available CloudSat and KAZR samples used to estimate reflectivity offset
units = 1
missing_value:int = -9999

radar_first_top(time):float
long_name = KAZR top height of lowest significant detection layer, before clutter removal
units = m
missing_value:float = -9999
valid_range:float = 0, 25000
flag_values:float = -1
flag_meanings = clear_sky

mean_doppler_velocity_dealias_flag(time, height):short
long_name = Indication of whether or not dealiasing was performed on the mean_doppler_velocity
units = 1
missing_value:short = -9999
flag_values:short = 0, 1

flag_meanings = no_dealias dealias
flag_0_description = No dealiasing performed
flag_1_description = Dealiasing performed
_DeflateLevel:int = 2
_ChunkSizes:int
_Shuffle = false

radar_mode_flag(time, height):short
long_name = Radar mode flag
units = 1
flag_values:short = 0, 1, 2, 3, 4
flag_meanings = No_significant_detection High_sensitivity_mode-long_pulse Medium_sensitivity_mode-long_pulse General_mode-short_pulse Precipitation_mode-short_pulse-attenuated
flag_0_description = No significant detection
flag_1_description = High sensitivity mode (long pulse)
flag_2_description = Medium sensitivity mode (long pulse)
flag_3_description = General mode (short pulse)
flag_4_description = Precipitation mode (short pulse, attenuated)
missing_value:short = -9999
_DeflateLevel:int = 3
_ChunkSizes:int
_Shuffle = false

cloud_source_flag(time, height):short
long_name = Instrument source flag for cloud (hydrometeor) detections
units = 1
flag_values:short = 0, 1, 2, 3, 4, 5, 6
flag_meanings = No_detection_due_to_missing_radar_and_micropulse_lidar_data clear_according_to_radar_and_lidar cloud_detected_by_radar_and_lidar cloud_detected_by_radar_only cloud_detected_by_lidar_only cloud_detected_by_radar_but_lidar_data_missing cloud_detected_by_lidar_but_radar_data_missing
flag_0_description = No detection due to missing radar and micropulse lidar data
flag_1_description = Clear according to radar and lidar
flag_2_description = Cloud detected by radar and lidar
flag_3_description = Cloud detected by radar only
flag_4_description = Cloud detected by lidar only
flag_5_description = Cloud detected by radar but lidar data missing
flag_6_description = Cloud detected by lidar but radar data missing
_DeflateLevel:int = 2
_ChunkSizes:int
_Shuffle = false

precip_mean(time):float
long_name = Precipitation mean from rain gauge
units = mm/hr

missing_value:float = -9999
ancillary_variables = qc_precip_mean

qc_precip_mean(time):int
long_name = Quality check results on variable: Precipitation mean from rain gauge
units = 1
description = This variable contains bit-packed integer values, where each bit represents a QC test on the data. Non-zero bits indicate the QC condition given in the description for those bits; a value of 0 (no bits set) indicates the data has not failed any QC tests.
flag_method = bit
bit_1_description = Not used
bit_1_assessment = Bad
bit_2_description = Not used
bit_2_assessment = Bad
bit_3_description = Data value not available in input file, data value has been set to missing_value.
bit_3_assessment = Bad
standard_name = quality_flag

mwr_lwp(time):float
long_name = Liquid water path best-estimate from microwave radiometer
units = g/m^2
ancillary_variables = qc_mwr_lwp
missing_value:float = -9999

qc_mwr_lwp(time):int
long_name = Quality check results on variable: Liquid water path best-estimate from microwave radiometer
units = 1
description = This variable contains bit-packed integer values, where each bit represents a QC test on the data. Non-zero bits indicate the QC condition given in the description for those bits; a value of 0 (no bits set) indicates the data has not failed any QC tests.
flag_method = bit
bit_1_description = Not used
bit_1_assessment = Bad
bit_2_description = Not used
bit_2_assessment = Bad
bit_3_description = Data value not available in input file, data value has been set to missing_value.
bit_3_assessment = Bad
standard_name = quality_flag

cloud_base_best_estimate(time):float*
long_name = Cloud base best estimate, based on ceilometer and micropulse lidar
units = m
missing_value:float = -9999
valid_range:float = 0, 25000
flag_values:float = -2, -1

flag_meanings = possible_clear_sky clear_sky
comment = -2. Possible clear sky (No MPL observations available, Ceilometer obscured, but no cloud detected), -1. Clear sky, >= 0. Valid cloud base height
standard_name = cloud_base_altitude

cloud_layer_base_height(time, layer):float*
long_name = Base height of hydrometeor layers for up to 10 layers, based on combined radar and micropulse lidar observations
units = m
missing_value:float = -9999
valid_range:float = 0, 25000
flag_values:float = -1
flag_meanings = clear_sky

cloud_layer_top_height(time, layer):float*
long_name = Top height of hydrometeor layers for up to 10 layers, based on combined radar and micropulse lidar observations
units = m
missing_value:float = -9999
valid_range:float = 0, 25000
flag_values:float = -1
flag_meanings = clear_sky

cloud_mask_mpl(time, height):short
long_name = Cloud mask from 30smplcmask1zwang
units = 1
missing_value:short = -9999
flag_values:short = 0, 1, 2
flag_meanings = clear cloudy mask_not_used_to_determine_cloud_boundaries_below_3km
flag_0_description = clear
flag_1_description = cloudy
flag_2_description = Mask not used to determine cloud boundaries below 3km
comment = Cloud mask indeterminate below 500 m

instrument_availability_flag(time):short
long_name = Indicates which instruments have data available
units = 1
flag_masks:short = 1, 2, 4, 8, 16
flag_meanings = KAZR MPL Ceilometer MWR rain_gauge
bit_1_description = KAZR
bit_2_description = MPL
bit_3_description = Ceilometer
bit_4_description = MWR
bit_5_description = rain gauge

lat():float

long_name = North latitude
units = degree_N
valid_min:float = -90
valid_max:float = 90
standard_name = latitude

lon():float
long_name = East longitude
units = degree_E
valid_min:float = -180
valid_max:float = 180
standard_name = longitude

alt():float
long_name = Altitude above mean sea level
units = m
standard_name = altitude

command_line
Conventions = ARM-1.3
process_version
dod_version
input_datastreams
site_id
platform_id
facility_id
data_level
location_description
datastream
title = Statistical alignment of ARM Active Remove Sensing of CLouds (ARSCL) VAP reflectivities with spaceborne 94GHz CloudSat profiling radar
references = Kollias, P., Puigdomènech Treserras, B., and Protat, A.: Calibration of the 2007–2017 record of ARM Cloud Radar Observations using CloudSat, Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2019-34, 2019.
doi = 10.5439/1728666
_Format = netCDF-4 classic model
radar_polarization_status
radar_modes_in_use
maximum_clutter_height
radar_operating_frequency_burst
radar_operating_frequency_chirp
history

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