User's Guide

SACR(m) SOFTWARE v 1.1

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1 Introduction

SACR(m) is the software that performs the data quality control and post-processing of the calibrated Scanning ARM Cloud Radars (*SACR*) measurements. It is written in both Matlab (SACRm) and FORTRAN (SACR).

SACR(m) performs data quality control and post-processing of ingest data coming from scanning radars operating under Atmospheric Radiation Measurement (ARM) program. This package produces netcdf files for each individual scan after:

- The construction of hydrometeor mask and removal of not significant radar returns
- The attenuation correction for gasses using the nearest-in-time atmospheric sounding
- The correction for the velocity folding that makes use of a first guess for the true Doppler velocity using horizontal wind measurements from the nearest sounding
- The insect removal
- The removal of the second trip echo

If you use the SACR software to process data used in publication, an acknowledgment or reference to the paper would be appreciated. The following references should be used:

1. *Scanning ARM Cloud Radars. Part I: Operational Sampling Strategies. Pavlos Kollias, Nitin Bharadwaj, Kevin Widener, Ieng Jo, and Karen Johnson. Journal of Atmospheric and Oceanic Technology*

2. *Scanning ARM Cloud Radars. Part II: Data Quality Control and Processing. Pavlos Kollias, Ieng Jo, Paloma Borque, Aleksandra Tatarevic, Katia Lamer, Nitin Bharadwaj, Kevin Widener, Karen Johnson, and Eugene E. Clothiaux. Journal of Atmospheric and Oceanic Technology*

1.1 Differences between Fortran (SACR) and Matlab (SACRm) version

Original code SACRM is written in Matlab, and SACR basically translates Matlab codes to Fortran. The main difference is in the masking part. Some other subroutines may be slightly different than original Matlab subroutines. The reason for those differences is the fact that the improved speed when executing the Fortran code enables additional quality control features in post-processing that are computationally expensive to be kept in the Matlab release. The SACR user configuration options are expanded on in the Fortran version, and added features also comprise different type of messaging (the info, warning, status and error).

2 Installation, compilation and execution

2.1 SACRm

2.1.1 Installation

Get the latest version of the Matlab SACRm release. The source file is named sacrm_[release version].tar.gz.

Unpack the model by typing the following:

tar –xvf sacrm_[release version].tar.gz

Main distribution of *.m files in the directory **sacrm** is shown in Table 1.

Table 1: The list of SACRm Matlab source files

Name	***Description***
parameters.m	Main code that calls two main functions: read_raw_data_int and read_flprocessed_data_complete_sl_processing_int
read_raw_data_int.m	The first level processing including masking and curvature correction
read_flprocessed_data_complete_sl_processing_int.m	The second level processing including removal of the second trip echo, insects, folding correction and correction for gaseous attenuation
readnetcdf.m	Function that reads netcdf files coming from ARM archives
index_fix.m	Function that corrects values of indexes from ingest.
elevation_correction.m	Function for sorting elevations from the lowest to the highest. It also corrects for unwanted data between two consecutive scans
curvature_correction.m	Function for correcting the range and elevation for Earth's curvature. It also calculates vertical and horizontal distances away from the radar.
sacr_masking_iter.m	Function that performs masking using the 5x5 box filter
estimatenoise.m	Masking based on Hildebrand, P. H. and R. S. Sekhon, 1974 and/or on climatological noise data
write_first_level_processing_netcdf_int.m	Function that writes the output netcdf files for each individual scan after the first level processing
read_sounding.m	Function that reads the sounding netcdf files
read_merged_sounding.m	Function that reads the merged sounding netcdf files

gas_attenuation_rose98.m	Function that calculates attenuation by various gasses using the method of ROSENKRANZ (1998)
dealiasing.m	Function that de-aliases/unfolds Doppler velocity
sacr_masking_echo.m	Function that removes the second trip echo present at low elevations
sacr_masking_iter_2.m	Function performing additional "final" masking to further improve the quality of the final variables.
put_new_var_into_netcdf.m	Function adds the new processed variables to the existing netcdf file.

The **sacrm** directory contains the subdirectory called **sacr_aux** containing the climatological noise data files (Table 2). The naming convention for the climatological noise files is as follows:

[radar location]_noise_clear_sky_[radar].mat

where [radar location] could be "sgp", "pvc" or "nsa" and [radar] "kasacr" or "wbsacr".

The file *[radar location]_noise_clear_sky_[radar].mat* is the required input for the SACRm.

Table 2: List of climatological noise files contained in the sacrm/sacr_aux subdirectory

List of climatological noise data files	*Site*	*Radar*
sgp_noise_clear_sky_kasacr.mat	SGP	KaSACR
sgp_noise_clear_sky_wbsacr. mat	SGP	WbSACR
pvc_noise_clear_sky_kasacr. mat	PVC	KaSACR
pvc_noise_clear_sky_wbsacr.mat	PVC	WbSACR
nsa_noise_clear_sky_kasacr.mat	NSA	KaSACR
nsa_noise_clear_sky_wbsacr. mat	NSA	WbSACR
tmp_noise_clear_sky_kasacr.mat	TMP	KaSACR
tmp_noise_clear_sky_xasacr.mat	TMP	XaSACR
noise_generic.mat	-	-

Please, read the REAME file in this directory carefully. In case the climatological noise file is not available for the site the user wants to process, you could use the file *noise_generic.mat*.

2.1.2 Execution

In order to execute the model, you have to execute the file parameters.m at the matlab prompt:

parameters

The function parameters.m is also a kind of configuration file - various paths and specific user options are to be specified here. You have to edit the file previously, as the paths have to be adapted to your system configuration. For more details, see Section 3.1.

2.1.3 SACRm Algorithm

The **parameters.m** is the main code that calls two main functions:

1. read_raw_data_int .m

- **readnetcdf.m**
  It reads the input data coming from the ARM archive.

- **Index_fix.m**
  It corrects values of indexes from ingest.

- **read_merged_sounding .m** or **read_sounding.m**
  This function reads merged sounding data. The output variables are used to correct attenuation by gases and water vapor and insect removal. In case of merged sounding data not present, function read_sounding reads regular sounding data with the same output as read_merged_sounding.

- **elevation_correction.m**
  All scans are saved in the form of lowest elevation to highest elevation. It also corrects for unwanted data stored between two consecutive scans.

- **curvature_correction.m**
  This function corrects range and elevation for Earth's curvature and calculates vertical and horizontal distances away from the radar.

- **sacr_masking_iter.m and estimatenoise.m**
  These two functions are used to mask the data based on Hildebrand, P. H. and R. S. Sekhon, 1974: Objective determination of the noise level in Doppler spectra. There is an additional masking using a 5x5 box filter in order to further reduce points with suspicious data.

- **write_first_level_processing_netcdf_int.m**
  This function creates a netcdf file (.nc) for each individual scan.

Up to this point, the data has been divided in individual scan. The variables DBZ, VD, SW, LDR have been masked. SNR remains the same in case the user wants to compare with raw data coming from the data ingest.

The second function should be used ONLY and ONLY IF sounding and ceilometer files for the day being processed are available for the user.

2. read_flprocessed_data_complete_sl_processing_int.m

This function reads the netcdf files that were previously created by **read_raw_data_int .m,** and within this function:

A. Ceilometer data is used for insect removal.
B. Sounding data is used to correct for Doppler velocity aliasing.
C. Second trip echoes are removed
D. Second masking with 5x5 boxcar filter is used to further correct for unwanted suspicious data values.

- **readnetcdf.m**
  It reads the netcdf files created by **read_raw_data_int .m**

- **read_sounding.m**
  This function reads sounding data. The output variables are used to correct attenuation by gases and water vapor and insect removal.

- **sacr_masking_echo.m**
  This function removes second trip echoes present at low elevations.

- **gas_attenuation_rose98.m**
  This function calculates attenuation by various gases, using the method of ROSENKRANZ (1998) - -- reference "Water vapour microwave continuum absorption: a comparison of measurements and results".

- **dealiasing.m**
  This function de-aliases/unfolds Doppler velocity.

- **sacr_masking_iter_2.m**
  This function computes an additional mask to further improve the quality of the final variables.

- **put_new_var_into_netcdf.m**
  This function adds new processed data to the already existing netcdf file.

2.2 SACR

2.2.1 Installation

Get the latest version of the Fortran SACR release. The source file is named sacr_[release version].tar.gz.

Unpack the model by typing the following:

tar –xvf sacr_[release version].tar

Main distribution of *f90 files in the directory **sacr** is shown in Table 3.

Table 3: The list of SACR FORTRAN source files

Name	*Description*
sacr.f90	Main code
processing.f90	contains the subroutines needed for post-processing scanning radar data from ARM archive (masking, correction for gaseous attenuation, second echo removal, insect removal, folding correction..)
hroutines.f90	the collection of subroutines that complement the post-processing algorithms in processing.f90.
ReadInpNCDF_raw_data.f90	subroutines needed for reading the scanning radar netcdf data

	files from ARM archive. It also contains the subroutine for reading the climatological noise data file
ReadInpNCDF_ceilo_data.f90	subroutines needed for reading the ceilometer netcdf data files from ARM archive
ReadInpNCDF_sounding_data.f90	subroutines needed for reading the sounding netcdf data files from ARM archive
ReadInpNCDF_mergedsonde_data.f90	subroutines needed for reading the Merged Sounding netcdf data files from ARM archive
WriteOutNCDF.f90	subroutine for writing the output netcdf data files
radar_mods.f90	module that contains a number of subroutines for defining, (de-)allocating, and nullifying (or setting to the missed value) data types used in sacr
gasabs_module.f9	contains the subroutines for calculation of gaseous attenuation by various gases using the method of ROSENKRANZ (1998)
sort_mod.f90	contains subroutines needed for data sorting
write_messages_mod.f90	contains the subroutines for writing the control error, warning, info and progress messages

The **sacr** directory contains the subdirectory called **sacr_aux** containing the climatological noise data files (Table 4). The naming convention for the climatological noise files is as follows:

[radar location]_noise_clear_sky_[radar].dat

where [radar location] could be “sgp”, “pvc”, “tmp” or “nsa” and [radar] “kasacr” (for all mentioned sits), “wbsacr” (sgp”, “pvc”, “nsa”) and “xasacr” (“tmp” only).

The file >>[radar location]_noise_clear_sky_[radar].dat<< is the required input for the sacr.

Table 4: List of climatological noise files contained in the sacr/sacr_aux subdirectory

List of climatological noise data files	*Site*	*Radar*
sgp_noise_clear_sky_kasacr.dat	SGP	KaSACR
sgp_noise_clear_sky_wbsacr.dat	SGP	WbSACR
pvc_noise_clear_sky_kasacr.dat	PVC	KaSACR
pvc_noise_clear_sky_wbsacr.dat	PVC	WbSACR
nsa_noise_clear_sky_kasacr.dat	NSA	KaSACR
nsa_noise_clear_sky_wbsacr.dat	NSA	WbSACR
tmp_noise_clear_sky_kasacr.dat	TMP	KaSACR
tmp_noise_clear_sky_xasacr.dat	TMP	XaSACR
noise_generic.dat	-	-

In case the climatological noise file is not available for the site the user wants to process, the file *noise_generic.dat* should be used.

2.2.2 Compilation

It is assumed that you already have installed on your system:

- intel fortran compiler (or a Fortran 90 compatible compiler), and
- the netcdf library, available from www.unidata.ucar.edu/packages/netcdf.

Prior to compiling, you will have to edit the sacr/Makefile for your system. The Makefile should be updated in the following variables:

FC=Intel Fortran compiler

NC_INCLUDE= NetCDF "include" directory

NC_LIB= NetCDF "lib" directory

To compile the code: In the **sacr** directory, type the following:

```
make clean
make
```

A binary file "sacr" will appear in **sacr** directory after successful compilation.

2.2.3 Execution

To run the model, you have to execute the script "run_sacr.sh".

```
sh run_sacr.sh
```

This script is also a kind of configuration file - various paths and specific user options are to be specified here. You have to edit the script previously, as the paths have to be adapted to your system configuration. For more details, see Section 3.2.

2.2.4 SACR Algorithm

The SACR algorithm flow chart is shown in Figure 1. The main algorithms are depicted in blocks. The algorithm processes as depicted. Each of algorithms assigned by red color has a control switch and may be included or excluded from nominal run (see Table 6, part D).

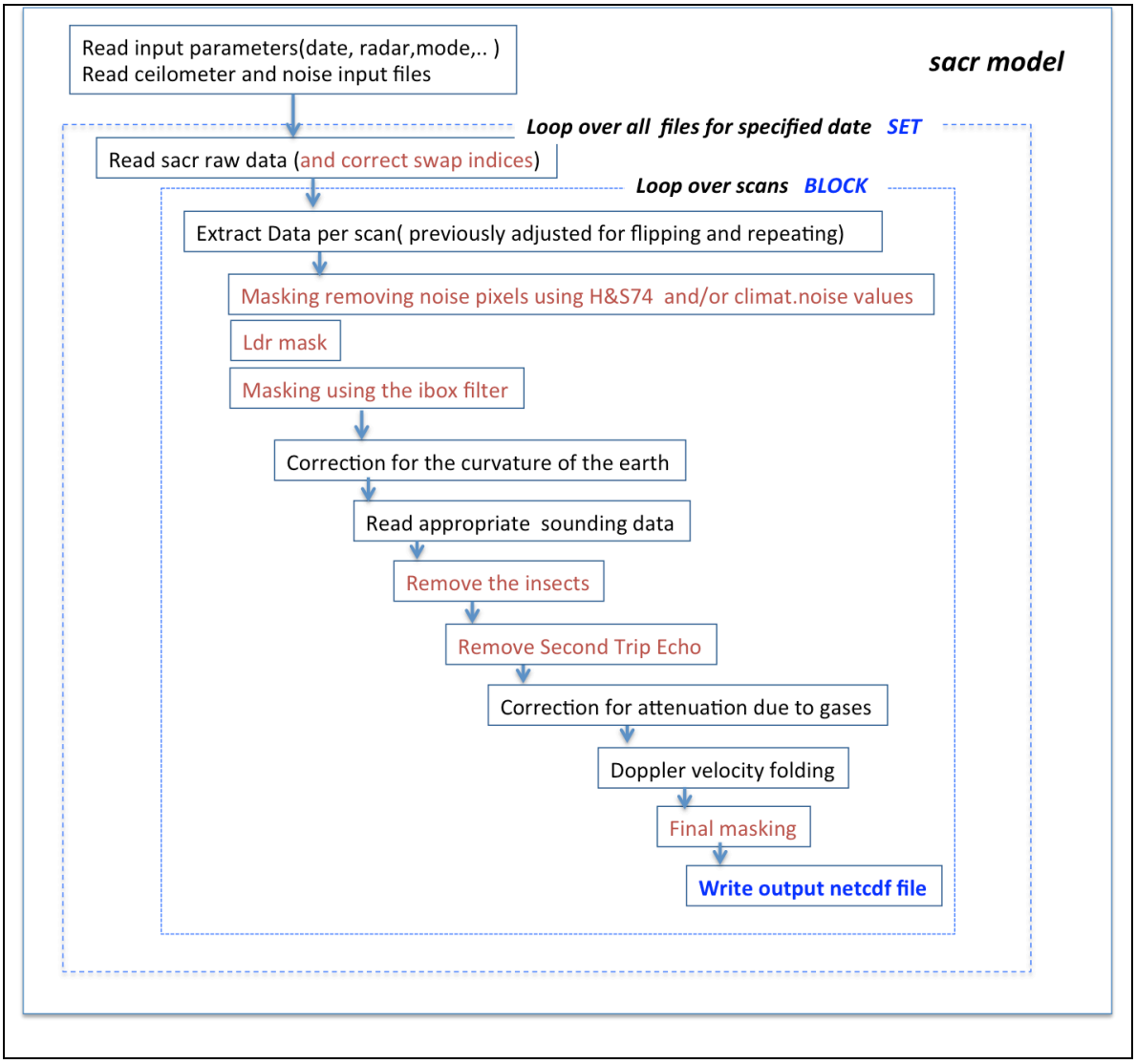

Figure 1: SACR algorithm flow chart.

3 I/O structure

3.1 SACRm Input configuration parameters

The parameters that have to be edited in the matlab file "parameters.m" are listed in Table 5.

Table 5: SACRm configuration parameters

Variable	*Possible configurations*	*Description*
Basic set of configuration parameters (case-sensitive)		
radar	KaSACR or WbSACR	radar name
location	SGP,NSA,PVC	radar location
date	YYYYMMDD	Calendar date in format YYYYMMDD, with [YYYY] indicating a four-digit year, and [MM] and [DD] two-digits moth and day respectively
mode	hsrhi,blrhi, vptmo, ppimo, cwrhi,awrhi	Mode of scanning
Paths specifications of input and output directories (case-sensiive)		
path_noise_clear_sky	'/sacrm/sacr_aux/'	Full location of the climatological noise data
path_common_data	"/common_path/"	Common path for the ARM data
path_raw_data	"/path_common_data/location/ raw_data/radar/mode_data/"	Full path of the directory where the raw SACRm data are located for specific location, radar and scanning strategy
path_sounding_data	"/path_common_data/location/ raw_data/sounding_data/"	Full path of the directory where the sounding data are located for specific location
path_ceilo_data	"/path_common_data/location/ raw_data/ceilo_data/"	Full path of the directory where the ceilometer data are located for specific location
path_processed_data	"/path_common_data/location/ raw_data/processed_data/"	Full path of the directory where the output data will be created

3.2 SACR Input configuration parameters

The parameters that have to be edited in the shell script "run_sacr.sh" are listed in Table 6.

Table 6: SACR configuration parameters

Variable	*Possible configurations*	*Description*
A: Basic set of configuration parameters (case-sensitive)		
radar	KaSACR,WbSACR,XaSACR	radar name
location	SGP,NSA,PVC,TMP	radar location
date	YYYYMMDD	Calendar date in format YYYYMMDD, with [YYYY] indicating a four-digit year, and [MM] and [DD] two-digits moth and day respectively
mode	hsrhi,blrhi, vptmo, ppimo, cwrhi,awrhi	Mode of scanning
B: Paths specifications of home, input and output directories (case-sensitive)		
SACR_HOME	"[user path]/sacr/"	Full path of the **sacr** location at user system
path_noise_clear_sky	"$SACR_HOME/ sacr_aux/"	Full location of the climatological noise data
path_common_data	"[common_path]/"	Common path for the ARM data
path_raw_data	"${path_common_data}${location}/ raw_data/${radar}/${mode}_data/"	Full path of the directory where the raw SACR data are located for specific location, radar and scanning strategy
path_mergedsonde_data	"${path_common_data}${location}/ raw_data/megedsonde_data/" "NULL"	Full path of the directory where the merged sounding data are located for specific location. If "NULL", this input is disregarded.
path_sounding_data	"${path_common_data}${location}/ raw_data/sounding_data/" "NULL"	Full path of the directory where the sounding data are located for specific location. If "NULL", this input is disregarded.
path_ceilo_data	"${path_common_data}${location}/ raw_data/ceilo_data/" "NULL"	Full path of the directory where the ceilometer data are located for specific location. If "NULL", this input is disregarded.
path_processed_data	"${path_common_data}${location}/ processed_data/"	Full path of the directory where the output data will be created
C: Settings influencing the algorithm performance		
csweep	1 or 0	Apply the correction for the sweep indices =1 yes, =0 no Option "csweep=1" is highly recommended. For the moment option "csweep=0" is rather

		obsolete and may cause the failure of execution or the incorrect execution of the code as a consequence of not proper input.
ste_el_min	Up to ~15°	Apply the correction for the second trop echo below ste_el_min and above ste_el_max
ste_el_max	Above ~165°	
ste_vel_thresh	~1.5 m/s	Threshold value of velocity standard deviation in m/s for the second trip echo identification; if std > ste_vel_thresh the cloud pixel is identified as the sec.trip echo
ir_ldr_thresh	Valid range from -15 to -5 dB	LDR threshold in dB for the insect removal below MIN (first cloud base height, 5 degrees isotherm height), insects if LDR> ir_ldr_thresh
D: Options for the testing/debugging the specific parts of algorithms NOTE: all of the following parameters should be equal to 1 in nominal runs		
irID	1 or 0	whether or not to apply the insect removal, =1 yes,=0 no
steID	1 or 0	whether or not to apply the second trip echo removal, =1 yes,=0 no
M1ID	1 or 0	whether or not to apply the mask1 (removing noise pixels using H&S74 and/or climat.noise values), =1 yes,=0 no
M2ID	1 or 0	whether or not to apply the ldr mask, =1 yes,=0 no
M3ID	1 or 0	whether or not to apply the masking using the ibox filter, =1 yes,=0 no
fmID	1 or 0	whether or not to apply the final masking, =1 yes,=0 no

Note that if required input files are present in both specified directories "path_mergedsonde_data" and "path_sounding_data", the model will use merged soundings. User can intentionally exclude mergedsounde, sounding or ceilometer data by defining "NULL" for "path_mergedsonde_data", "path_sounding_data" and "path_ceilo_data", respectively. If not "NULL", required input data will be looked for in specified directories, and, a) if found written in appropriate input *list files (see Section 3.4.3, Table 10), b) if not found, a single line "NULL" will be written in appropriate input *list files.

Also note that variables "sweep_start_ray_index" and "sweep_end_ray_index" are not properly defined in the ARM scanning radar netcdf data files. For some cases values of "fixed_angle" may not be correct. They are to be corrected in near future. In mean time those indices are correctly re-calculated here and it is strongly recommended that configuration parameter "csweep" is equal to one (csweep=1) in all user runs. The option "csweep=0" is not guaranteed to lead to the correct results when executing the code and is rather obsolete.

3.3 SACR(m) Input data

The required input files for both SACR and SACRm are listed in Table 7.

Table 7: List of input files and input variables

INSTRUMENT	*VARIABLE*	*UNITS*	*DESCRIPTION*
Naming convention	**{location}{radar}{mode}C1.b1.YYYYMMDD.HHMMSS.nc**		
SACR scanning radar	base_time	sec	seconds since 1970-1-1 0:00:00 0:00
SACR scanning radar	time_offset	sec	Time offset from base_time
SACR scanning radar	range	m	Range to measurement volume
SACR scanning radar	azimuth	degrees	Azimuth angle from true North
SACR scanning radar	elevation	degrees	Elevation angle from horizontal
SACR scanning radar	reflectivity	dBZ	Equivalent reflectivity factor
SACR scanning radar	mean_doppler_velocity	m/sec	Mean Doppler velocity (negative towards instr.)
SACR scanning radar	snr	dB	Signal-to-noise-ratio
SACR scanning radar	linear_depolarization_ratio	dB	Linear depolarization ratio H
SACR scanning radar	spectral_width	m/sec	Spectrum width
SACR scanning radar	sweep_number	-	Number of sweeps, 1-based (Recomputed values used)
SACR scanning radar	fixed_angle	degrees	Target angle for sweep (Recomputed values used)
SACR scanning radar	sweep_start_ray_index	-	Index of first ray in sweep, 1-based (Recomputed values used)
SACR scanning radar	sweep_end_ray_index	-	Index of last ray in sweep, 1-based (Recomputed values used)
SACR scanning radar	frequency	Hz	Operating frequency
SACR scanning radar	nyquist_velocity	m/sec	Unambiguous Doppler velocity
SACR scanning radar	lat	degrees	Cite latitude
SACR scanning radar	lon	degrees	Cite longitude
SACR scanning radar	alt	m	Altitude above mean sea level
SACR scanning radar	alt_agl	m	Altitude above ground level
Naming convention	**{location}mergesonde1maceC1.c1.YYYYMMDD.HHMMSS.cdf**		
MERGESONDE	time	sec	Time offset from midnight
MERGESONDE	height	km	Height above MSL
MERGESONDE	temp	Degrees C	Temperature

MERGESONDE	qc_temp	-	Quality check parameter for temp
MERGESONDE	bar_pres	kPa	Barometric pressure
MERGESONDE	qc_bar_pres	-	Quality check parameter for bar_pres
MERGESONDE	rh	%	Relative humidity
MERGESONDE	qc_rh	-	Quality check parameter for rh
MERGESONDE	wspd	m/sec	Wind speed
MERGESONDE	qc_wspd	-	Quality check parameter for wspd
MERGESONDE	wdir	Degrees	Wind direction
MERGESONDE	qc_wdir	-	Quality check parameter for wdir
Naming convention	**{location}sondewnpnC1.b1.YYYYMMDD.HHMMSS.cdf**		
SOUNDING	tdry	Degrees C	Dry Bulb Temperature
SOUNDING	qc_tdry	-	Quality check parameter for tdry
SOUNDING	pres	hPa	Pressure
SOUNDING	qc_pres	-	Quality check parameter for pres
SOUNDING	rh	%	Relative humidity
SOUNDING	qc_rh	-	Quality check parameter for rh
SOUNDING	alt	m	Altitude above mean sea level
SOUNDING	wspd	m/sec	Horizontal wind speed
SOUNDING	qc_wspd	-	Quality check parameter for wspd
SOUNDING	deg	degrees	Wind direction from true North
SOUNDING	qc_deg	-	Quality check parameter for deg
Naming convention	**{location}vceil25kC1.b1.YYYYMMDD.HHMMSS.cdf**		
CEILOMETER	base_time	sec	seconds since 1970-1-1 0:00:00 0:00
CEILOMETER	time_offset	sec	Time offset from base_time
CEILOMETER	first_cbh	m	Lowest cloud base height detected above ground level
CEILOMETER	qc_first_cbh	-	Quality check parameter for first_cbh
CEILOMETER	detection_status	-	Detection status =0 No significant backscatter; =1,2, or 3 – number of cloud bases detected; =4 Full obscuration but no cloud base detected =5 Some obscuration detected but determined to be transparent =9999 Raw data input to algorithm missing or suspect
CEILOMETER	qc_detection_status	-	Quality check parameter for detection_status
CEILOMETER	alt	m	Altitude above mean sea level
Naming convention	**{location}_noise_clear_sky_{radar}.dat**		
clear sky climatological noise	n_mean	dB	Mean clear sky climatological noise for elevation angles from 0 to 179 degrees
clear sky climatological noise	n_std	dB	Standard deviation of clear sky climatological noise for elevation angles from 0 to 179 degrees

Note that brackets {} used in above mentioning naming conventions stand for lowercase configuration parameters “$radar”, “$location” and “$mode.

The following parameters are read but rather considered highly suspicious: sweep_number, fixed_angle, sweep_start_ray_index, sweep_end_ray_index. These parameters are redetermined by the code.

3.4 SACR(m) Output data

The SACR(m) produces the set of netcdf output files, each corresponding to one specific observational scan, for fixed (azimuth or elevation) angle. The naming convention of produced data files is as following:

{radar}_{mode}_mode_set_SSS_block_BBB_{fixed_angle}_AAA_YYYYMMDD_HHMMSS.nc

where:

{radar} – lowercase for the configuration parameter $radar

{mode} – lowercase for the configuration parameter $mode

SSS – three-digits set number, where set refers to the counting number of input SACR raw input data files for the specific date

BBB – three-digits block number, where block refers to the counting number of scans for each set

{fixed_angle} – string “azimuth” or “elevati” for fixed scanning angle, depending on scanning strategy

AAA – three-digits rounding value of fixed_angle in degrees

YYYY – four-digits year

MM – two-digits month

DD – two-digits month

HH, MM and SS – two-digits hour, minute and second respectively corresponding to the time at the middle of the scan.

An example of the global attributes field in created netcdf file is given bellow. Note that the names of specific input files used in processing are preserved.

```
// global attributes:
        :content = "This file contains one scan of remotely sensed data" ;
        :conventions = "Scanning Remote Sensor at SGP site" ;
        :Instrument_Name = "KaSACR" ;
        :Instrument_Type = "ground" ;
        :Scan_Mode = "hsrhi" ;                    :
        :Time_at_the_middle_of_the_scan = "20110526_000743" ;
        :description = "Netcdf File for the KaSACR mode hsrhi" ;
        :input_radar_file = "sgpkasacrhsrhiC1.a1.20110526.000633.nc" ;
        :input_sounding_file = "sgpmergesonde1maceC1.c1.20110526.000000.cdf" ;
        :input_ceilometer_file = "sgpvceil25kC1.b1.20110526.000008.cdf" ;
        :created_by = "sacr_v1.1" ;
        :author = "http://wwww.clouds.mcgill.ca" ;
        :institute = "http://wwww.clouds.mcgill.ca" ;
```

3.4.1 SACRm output data structure (*matlab*)

The list of the variables contained in each output file produced by SACRm v1.1 is given in Table 8.

Table 8: The structure of SACRm output netcdf files

DIMENSION NAMES	Description	Comment
maxCells	Number of range gates	-
time	Number of records	-
numone	=1	-
sounde	Number of soundings	Not included if both sounding and merged sounding data are not available

VARIABLE	DIMENSION	UNITS	DESCRIPTION
scan_time	time	sec	Unix Date/Time value for every record in seconds since 1970-0101 00:00 UTC
radar_time	time	hour	Time from midnight for every record

m_time	numone	sec	Unix Date/Time value for the record at the middle of the scan in seconds since 1970-0101 00:00 UTC
Range	maxCells	km	Range to measurement volume
Fixed_Angle	numone	degrees	Targeted fixed angle for this scan
Range_to_First_Cell	numone	m	Range to the center of the first cell
radar_frequency	numone	GHz	Radar frequency
Nyquist_Velocity	numone	m/sec	Unambiguous Doppler velocity
Latitude	numone	degrees	Latitude of the instrument
Longitude	numone	degrees	Longitude of the instrument
Altitude	numone	m	Altitude of radar instrument above mean sea level
Altitude_fgl	numone	m	Altitude of radar instrument above the ground level
Azimuth	time	degrees	Azimuth angle from true east in degrees counter-clockwise from true east
Elevation	time	degrees	Elevation angle from horizontal
elevation_corrected	maxCells, time	degrees	Elevations corrected for the earth curvature
Range_corrected	maxCells, time	km	Range corrected for the earth curvature
x_distance	maxCells, time	km	X_distances corrected for the earth curvature
z_distance	maxCells, time	km	Z_distances corrected for the earth curvature
DBZ_received_power	maxCells, time	dBZ	DBZ received power
DBZ	maxCells, time	dBZ	Equivalent reflectivity factor
VR	maxCells, time	m/sec	Radial mean Doppler velocity (negative towards the instrument
SW	maxCells, time	m/sec	Spectrum width
SNR	maxCells, time	dB	Signal to Noise Ratio
LDR	maxCells, time	dB	Linear depolarization ratio
Included only if sounding or merged sounding input file available			
dt_sounding_scan	numone	sec	Time interval between the sacr scan time and the closest sounding
DBZ_cor	maxCells, time	dBZ	Reflectivity corrected for gaseous attenuation
Temperature	sounde	C	Temperature from sounding (sounding, merged sounding) in degrees C
height	sounde	km	Height above MSL from (sounding, merged sounding)
wspd_sounding	sounde	m/sec	Wind speed from sounding (sounding, merged sounding)
wdir_sounding	sounde	degrees	Wind direction from sounding in degrees from East (sounding, merged sounding)
wf	maxCells, time	m/sec	Wind force in radar coordinates
wd	maxCells, time	degrees	Wind direction in radar coordinates in degrees clockwise from true east
Up_90	maxCells, time	m/sec	Wind speed from sounding projected 90 degrees to the radar scan
Up_az	maxCells, time	m/sec	Wind speed from sounding projected to the azimuth of radar scan
Up_az_el	maxCells, time	m/sec	Wind speed from sounding projected to the azimuth and elevation of radar scan
aliasn	maxCells, time	-	Number of aliasing
VD_unfolded	maxCells, time	m/sec	Unfolded Doppler Velocity, negative towards the instrument

VD_unf_flag	time	-	de-aliasing quality control (=0 correction failed, =1 correction works)
percentage_flag	numone	%	100 x (number of rays where folding correction failed /number of rays with cloud)

3.4.2 SACR Output data file structure (*fortran*)

The list of the variables contained in each output file produced by sacr v1.1 is given in Table 9.

Table 9: The structure of SACR output netcdf files

DIMENSION NAMES	Description	Comment
maxCells	Number of range gates	-
time	Number of records	-
numSystems	=1	-
sounde	Number of soundings	Not included if both sounding and merged sounding data are not available

VARIABLE	DIMENSION	UNITS	DESCRIPTION
scan_time	time	sec	Unix Date/Time value for every record in seconds since 1970-0101 00:00 UTC
radar_time	time	hour	Time from midnight for every record
m_time	numSystems	sec	Unix Date/Time value for the record at the middle of the scan in seconds since 1970-0101 00:00 UTC
Range	maxCells	km	Range to measurement volume
Fixed_Angle	numSystems	degrees	Targeted fixed angle for this scan
Range_to_First_Cell	numSystems	m	Range to the center of the first cell
radar_frequency	numSystems	GHz	Radar frequency
Nyquist_Velocity	numSystems	m/sec	Unambiguous Doppler velocity
Latitude	numSystems	degrees	Latitude of the instrument
Longitude	numSystems	degrees	Longitude of the instrument
Altitude	numSystems	m	Altitude of radar instrument above mean sea level
Altitude_fgl	numSystems	m	Altitude of radar instrument above the ground level
Azimuth	time	degrees	Azimuth angle from true east in degrees counter-clockwise from true east
Elevation	time	degrees	Elevation angle from horizontal
elevation_corrected	maxCells, time	degrees	Elevations corrected for the earth curvature

Range_corrected	maxCells, time	km	Range corrected for the earth curvature
x_distance	maxCells, time	km	X_distances corrected for the earth curvature
z_distance	maxCells, time	km	Z_distances corrected for the earth curvature
DBZ_received_power	maxCells, time	dBZ	DBZ received power
DBZ	maxCells, time	dBZ	Equivalent reflectivity factor
VR	maxCells, time	m/sec	Radial mean Doppler velocity (negative towards the instrument
SW	maxCells, time	m/sec	Spectrum width
SNR	maxCells, time	dB	Signal to Noise Ratio
LDR	maxCells, time	dB	Linear depolarization ratio
M1_flag	numSystems	-	Configuration parameter indicating if MASK 1 (removing noise pixels using H&S74 and/or climat. noise values) is applied (=1) or not (=0)
M2_flag	numSystems	-	Configuration parameter indicating if MASK 2 (removing false detection streaks along radial using ldr) is applied (=1) or not (=0)
M3_flag	numSystems	-	Configuration parameter indicating if MASK 3 (using i-box filter) is applied (=1) or not (=0)
M4_flag	numSystems	-	Configuration parameter indicating if MASK 4 (final masking at the end of processing) is applied (=1) or not (=0)
mergedsonde_flag	numSystems	-	Parameter indicating if mergedsonde data are available (=1) or not (=0)
sounde_flag	numSystems	-	Parameter indicating if sounde data are available (=1) or not (=0)
ceilo_flag	numSystems	-	Parameter indicating if ceilometer data are available (=1) or not (=0)
Included only in the case mergedsonde_flag=1 OR sounde_flag=1			
dt_sounding_scan	numSystems	sec	Time interval between the sacr scan time and the closest sounding
DBZ_cor	maxCells, time	dBZ	Reflectivity corrected for gaseous attenuation
Temperature	sounde	C	Temperature from sounding (sounding, merged sounding) in degrees C
height	sounde	km	Height above MSL from (sounding, merged sounding)
wspd_sounding	sounde	m/sec	Wind speed from sounding (sounding, merged sounding)
wdir_sounding	sounde	degrees	Wind direction from sounding in degrees from East (sounding, merged sounding)
wf	maxCells, time	m/sec	Wind force in radar coordinates
wd	maxCells, time	degrees	Wind direction in radar coordinates in degrees clockwise from true east
Up_90	maxCells, time	m/sec	Wind speed from sounding projected 90 degrees to the radar scan
Up_az	maxCells, time	m/sec	Wind speed from sounding projected to the azimuth of radar scan
Up_az_el	maxCells, time	m/sec	Wind speed from sounding projected to the azimuth and elevation of radar scan

aliasn	maxCells, time	-	Number of aliasing
VD_unfolded	maxCells, time	m/sec	Unfolded Doppler Velocity, negative towards the instrument
VD_unf_flag	time	-	de-aliasing quality control (=0 correction failed, =1 correction works)
percentage_flag	numSystems	%	100 x (number of rays where folding correction failed /number of rays with cloud)
Included only if scanning mode /= "vptmo"			
csweep_flag	numSystems	-	Configuration parameter indicating if correction for sweep indices is applied (=1) or not (=0)
ste_flag	numSystems	-	Configuration parameter indicating if correction for the second trip echo removal is applied (=1) or not (=0)
ste_el_min	numSystems	degrees	Configuration parameter indicating the elevation value below which the second trip echo occurrence is checked (measured in degrees counterclockwise from true east)
			Included in the output only if **ste_flag=1**
ste_el_max	numSystems	degrees	Configuration parameter indicating the elevation above which the second trip echo occurrence is checked (measured in degrees counterclockwise from true east)
			Included in the output only if **ste_flag=1**
ste_vel_thresh	numSystems	m/sec	Configuration parameter indicating the threshold value of velocity standard deviation used for identification of second trip echo
			Included in the output only if **ste_flag=1**
Not Included only in the case mergedsonde_flag=0 & sounde_flag=0 & ceilo_flag=0			
ir_flag	numSystems	-	Configuration parameter indicating if correction for the insect removal is applied (=1) or not (=0)
ir_ldr_thresh	numSystems	dB	Configuration parameter indicating the value of LDR threshold that is applied for the insect removal
			Included in the output only if **ir_flag=1**

3.4.3 Additional SACR input/output (only Fortran version)

In addition, along with each run of the model, a number of *.list files is generated. Each of those *.list files contains the full path names of input files used by model and also the full path names of generated output files (see Table 10).

Table 10: List files generated along the run

Names of list files produced along the run	Content
INPUT FILES created by shell script	
path_raw_data_${location}_${radar}_${mode}_${date}.list	Full path names of ARM scanning radar netcdf files used as input
path_mergedsonde_data_${location}_${radar}_${mode}_${date}.list	Full path names of merged sounding netcdf files used as input. If configuration parameter path_mergesonde_data="NULL" or merged sounding not found, the "NULL" will be written into the list file.
path_sounding_data_${location}_${radar}_${mode}_${date}.list	Full path names of sounding netcdf files used as input. If configuration parameter path_sounding_data="NULL" or sounding not found, the "NULL" will be written into the list file.
path_ceilometer_data_${location}_${radar}_${mode}_${date}.list	Full path names of ceilometer netcdf files used as input. If configuration parameter path_ceilo_data="NULL" or ceilometer data not found, the "NULL" will be written into the list file.
OUTPUT FILES created by shell script	
processed_output_files_${location}_${radar}_${mode}_${date}.list	Full path names of created output netcdf files

4 Changes since initial release of the model

4.1 SACR MATLAB CODE

Version 1.1 (05 28 2014)

- The second release of the model

- The following changes will appear in the written output netcdf file:
  - The order of written output variables is changed.
  - Global attributes include the name and version of the software. Also included are the names of the radar input file, sounding file (sounding or merged sounding) and ceilometer file.
  - Added a new output variable "dt_sounding_scan" specifying a time interval between the scan time and the closest sounding in seconds.

- All relevant quality control parameters in input ceilometer, sounding and mergedsonde data are included when pre-processing the input data.

- Merged soundings are introduced as an possible input:
  - mergedsonde_data_file list file is introduced as an input file
  - Code looks first if the merged data are available, if not it checks for soundings, and if soundings are not available, it proceeds to run without this input.

- Code optimized to run even if there is no input ceilometer or sounding data.

- Added climatological noise files for TMP KaSACR and XaSACR.

- Rewritten function read_raw_data_int.m that corrects the sweep indices for modes different than "ppimo". Added function index_fix.m that corrects values of indices for all modes but vpt.

- Function write_first_level_processing_netcdf_int.m rewritten. It now saves only variables present in the ingest data.

- New function read_merged_sounding.m introduced to read merged sounding data, in case it exists.

- New function put_new_var_into_netcdf.m is introduced in the main function read_flprocessed_data_complete_sl_processing_int.m. It adds the newly processed variables during the second processing stage.

Version 1.0 (03 28 2014)
- The first release of the model

4.2 SACR FORTRAN CODE

Version 1.1 (05 28 2014)
- The second release of the model

- The following changes will appear in the written output netcdf file:
  - The order of written output variables is changed.
  - Missing value for all variables changed from -999.e0 to -999.d0
  - The configuration parameters figuring in the script added in the output ncdf file.
  - Added new output variables mergedsonde_flag, sounde_flag, ceilo_flag indicating if the corresponding data were available (=1) or not (=0) for the run.
  - Global attributes include the name and version of the software
  - The output data structure made dependent of the configuration parameters, for example: if mergedsonde_flag=0 and sounde_flag=0, the variables not present in the output file are all sounding variables and all variables related to velocity folding and attenuation correction. See User Guide for more details.
  - Added a new output variable "dt_sounding_scan" specifying a time interval between the scan time and the closest sounding in seconds.

- All relevant quality control parameters in input ceilometer, sounding and mergedsonde data are included when pre-processing the input data.

- Merged soundings are introduced as an possible input:
  - mergedsonde_data_file list file is introduced as an input file
  - Code looks first if the merged data are available, if not it checks for soundings, and if soundings are not available, it proceeds to run without this input

        - Also added option in configuration that enables the execution of the code with a-priori chosen merged soundings only or sounding data only.

    - Code optimized to run even if there is no input ceilometer or sounding data. Also added option in configuration to voluntarily exclude any of them.

    - Corrected bug with indices in EstimateNoiseFloor_yppi.

    - Added climatological noise files for TMP KasSACR and XaSACR. Also introduced a generic noise file as an input for sites without them.

    - Rewritten subroutine that corrects the sweep indices for modes different than "ppimo". The “ppimo” mode is now also corrected for indices. New subroutines CorrectSweepIndices and GetSweepIndices correctly compute the number of actual scans, fixed angles, based solemnly on observed elevation and azimuth and input information weather the fixed angle is whether azimuth or elevation.

    - Saved computations of wind speed and directions in radar coordinates in already existing output structure.

    - Corrected bug in the “IF” condition when calling CheckElFlippingAndRepeating for ppi and vpo mode (“.or.” replaced by “.and.”)

Version 1.0 (03 28 2014)

- The first release of the model