Microwave Integrated Retrieval System (MIRS)

External Users Manual
for NPP ATMS

Compiled by

NOAA Center for Satellite Applications and Research (STAR)
NOAA Office for Satellite and Product Operations (OSPO)
NOAA Office of Systems Development (OSD/NDE)

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DOCUMENT HISTORY
DOCUMENT REVISION LOG

The Document Revision Log identifies the series of revisions to this document since the baseline release. Please refer to the above page for version number information.

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Significant alterations made to this document are annotated in the List of Changes table.

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3.0	09/01/15	Grassotti	All	All	Updated to reflect v11.2 of MiRS

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1. PRODUCTS

The Microwave Integrated Retrieval System (MiRS) algorithm inverts passive microwave radiances into multiple geophysical parameters to explain the atmospheric and surface conditions for a given observation. Currently there are 13 operational products from 7 polar-orbiting satellite platforms, detailed below, and made available to external users (outside of NOAA). This document serves to focus on the MiRS products derived from the Suomi-NPP Advanced Technology Microwave Sounder (ATMS) instrument data.

The intended users of the External Users Manual (EUM) are end users of the NDE MiRS operational products files, and the product verification and validation (V&V) teams. The purpose of the EUM is to provide product users and testers with information that will enable them to acquire the product, understand its features, and use the data. External users are defined as those users who do not have direct access to the processing system (those outside of the OSPO and NDE). The output files are defined as those leaving the NDE DHS (running within ESPC) as opposed to those that are output by the MiRS processing, but available only internally within the NDE. The NDE MiRS does provide outputs for being tailored into McIDAS within ESPC. Those tailored files are described in a separate EUM.

1.1. Product Overview

1.1.1. Product Requirements

The MiRS was developed by the NOAA/NESDIS Center for Satellite Application and Research (STAR) as a major upgrade to the existing suite of microwave retrieval algorithms called the Microwave Surface and Precipitation Product System (MSPPS). MSPPS lacks profiling capability and is specific to a single instrument, the AMSU. Another objective for developing MIRS was to provide retrievals in all-weather and over all-surface conditions with the immediate benefits of extending the spatial coverage to critical areas such as active regions and using non-exploited measurements such as those made by surface-sensitive channels for temperature sounding.

MiRS is applicable to both existing and future microwave sensors. It is currently being applied operationally to the NOAA-18, NOAA-19, METOP-A and METOP-B AMSU/MHS suite, the DMSP-F18 SSMI/S sensor, to SNPP ATMS measurements, and to Megha-Tropiques (MT) SAPHIR data. In addition MIRS has been applied to TRMM TMI, Megha-Tropiques (MT) MADRAS, GCOM-W1 AMSR2, and GPM GMI data in research mode. It could also be a system for Infrared (IR) sensors onboard the JPSS and GOES-R platforms.

MiRS is applicable to both existing and future microwave sensors. It is currently being applied operationally to the NOAA-18, NOAA-19, METOP-A and METOP-B AMSU/MHS suite, the DMSP-F16 and F18 SSMI/S sensors, and to NPP ATMS. In addition MIRS is applied to TRMM TMI, Megha-Tropiques (MT) MADRAS and SAPHIR data in research mode. It could also be a system for Infrared (IR) sensors onboard the JPSS and GOES-R platforms. Having one retrieval system for a multitude of sensors is scientifically sound because the radiative transfer physics involved is by and large the same and the mathematical basis for the inverse problem is identical. The practical advantages of having one single system for a multitude of sensors are numerous. They include among others, the time and cost savings related to generating a retrieval algorithm for a new sensor, the optimal use of the information content and the consistent treatment of time series of satellite data for long-term trend monitoring and climate studies. MiRS is coupled with the Joint Center for Satellite Data Assimilation (JCSDA) Community Radiative Transfer Model (CRTM) which is valid in both microwave and infrared spectral regions, as well as in clear, cloudy and precipitating conditions and over all surface types.

Therefore, MiRS meets the following operational product requirements: temperature and humidity profiles in all-weather conditions, total precipitable water (TPW), land surface temperature (LST), surface emissivity, non-precipitating cloud water, ice/graupel, and rain profiles, as well as their integrated amounts (CLW, RWP, GWP), emissivity-based sea-ice concentration (SIC), sea ice age (SIA), snow water equivalent (SWE), snow effective grain size (SGS), snow cover extent (SCE), surface type classification (ST), and a high resolution surface rainfall rate (RR). Quality control metrics and flags defining retrieval product quality are also provided.

For operational processing of NPP ATMS data in the NPOESS Data Exploitation (NDE) environment, and transitioned to the NOAA Office for Satellite and Product Operations (OSPO) in the July 2013 timeframe, the MIRS algorithm provides the capability to convert MiRS product files to the NetCDF4 format following the Climate and Forecast convention and STAR metadata standards.

In both processing environments, two product files are created for each set of input observations (e.g. granule or orbit). One file, referred to as the sounding products file (SND) contains temperature and humidity profiles. The second file, referred to as the imaging products file (IMG), contains primarily products more responsive to surface sensitive channels including TPW, LST, CLW, RWP, IWP, surface emissivity, SIC, SIA, SWE, SGS, SCE, and RR.

1.1.2. Product Team

The MiRS product team is comprised by two entities, the development team and the operational team.

The MiRS development team (Table 1-1) consists of algorithm developers and scientists performing science and capability enhancements, extensions to new and future sensors, code maintenance, software version control, and algorithm delivery. This team is based at NOAA STAR.

Name	**Position**	**Affiliation**
Xiwu Zhan	Physical Scientist/Lead	NOAA/NESDIS/STAR
Christopher Grassotti	Scientist/Contractor Lead	U. Md/ESSIC @ NOAA/NESDIS/STAR
Mohar Chattopadhyay	Scientist	AER @ NOAA/NESDIS/STAR

Table 1-1. MiRS STAR product development team.

The MiRS operational team (

Clay Davenport	McIDAS Tailoring Algorithm Developer	SGT@OSPO

Table 1-2) consists of a Product Area Lead (PAL), algorithm integrators and monitors based at the NOAA OSPO and NDE, performing algorithm installation into operational environments, 24/7/365 job monitoring and support, and data dissemination to both internal and external users.

Name	**Position**	**Affiliation**
Limin Zhao	PAL	NOAA OSPO
Jiande Wang	Algorithm Integrator	NOAA OSPO
Clay Davenport	McIDAS Tailoring Algorithm Developer	SGT@OSPO

Table 1-2. MiRS operational team.

1.1.3. Product Description

The list of products generated by MiRS is summarized in Table 1-3. Also included is the list of heritage products, e.g., generated by MSPPS. “Standard” products are labeled those that have been routinely retrieved and for which extensive validation and testing has been done. Listed are the MiRS 1DVAR and derived products. MiRS 1DVAR products include the parameters that are part of the retrieval state vector. MiRS derived products are those generated using MiRS 1DVAR parameters as inputs and a post-processing procedure, e.g., a simple vertical integration of retrieved water vapor profile for computing TPW, or a new algorithm, e.g., for the estimation of SWE from the retrieved surface emissivities. Note in the table MiRS profiling capability, which is lacking in MSPPS. Note also the list of MiRS new products (1DVAR and derived) which would require new validation efforts.

Heritage Products	MiRS 1DVAR Products	MiRS derived products
Standard Products		
Total Precipitable Water (TPW)	Atmospheric temperature profile (T)	Q-based TPW
Cloud Liquid Water (CLW)	Atmospheric humidity profile (Q)	NPCP-based CLW
Land Surface Temperature (LST)	Land Surface Temperature (LST)	IGP-based IWP
Emissivity at certain window channels	Emissivity vector (Em)	RP-based Rain Water Path (RWP)
Rain Rate (RR)		Em-based SIC
Ice Water Path (IWP)		Em-based First-Year SIC
Snow Water Equivalent (SWE)		Em-based Multi-Year SIC
Sea Ice Concentration (SIC)		Em-based SCE
Snow Cover Extent (SCE)		Em-Based Surface Type
		CLW,RWP&IWP-based RR
		Em-based SWE
		Em-based Snow Effective Grain Size
		Snowfall Rate (SFR)*

Table 1-3. List of heritage, advanced and derived MiRS products. *Note that the SFR is an optional product based on MSPPS heritage algorithms currently requiring availability of ancillary NWP data from the GFS model. Processing of SNPP/ATMS data for SFR is not currently supported, but expected in future extensions.

1.2. Product History

Table 1-4 shows the development timeline for MiRS products and corresponding delivery of the Development Algorithm Package (DAP) for which the product became available in the operational environment.

Phase III was completed in June 2010, marking the delivery of all scheduled MiRS operational products excluding those from future sensors such as the NPP ATMS. In December 2012, DAP 8 was delivered to NDE with the capability to create NPP ATMS products from MiRS. The latest update (MiRS DAP 11.2) was delivered to NDE in September 2015, and products went to operations in January 2016.

Phase	Products Available	NOAA-18	MetopA	DMSP F16	NOAA-19	DMSP F18	NPP ATMS
I	- Atmospheric Temperature Profile (T) - Quality Control based on chi-sq (optional)	Sep. 2006 DAP1	June 15, 2007 DAP2	June 15, 2008 DAP4	June 15, 2009 DAP6	June 15, 2010 DAP7	Dec. 15, 2012 DAP8
I & II	- Water Vapor Profile (Q) - over ocean – - Total Precipitable Water (TPW) – over ocean- - Land Surface Temperature (LST) - Sea Surface	June 15, 2007 DAP2	June 15, 2007 DAP2	June 15, 2008 DAP4	June 15, 2009 DAP6	June 15, 2010 DAP7	Dec. 15, 2012 DAP8

	Temperature (SST) (optional) - Snow & Ice Surface Temperature (optional) - Emissivity over all surfaces - Emissivity for all channels - Surface Type Classification (Ocean, Sea-ice, Land, Snow)						
II	- Emissivity-based Snow Water Equivalent (SWE) - Em-based Snow Cover Extent (SCE) - Em-based Sea-ice Concentration (SIC) - Non-precipitating cloud water profile – ocean - Integrated CLW – ocean - TPW over non-ocean	Dec. 15, 2007 DAP3	Dec. 15, 2007 DAP3	Dec. 15, 2008 DAP5	June 15, 2009 DAP6	June 15, 2010 DAP7	Dec. 15, 2012 DAP8
II & III	- Ice profile & Ice Water Path (IWP) - Rain profile & Rain Water Path - Rain Flag (RF) (optional)	June 15, 2008 DAP4	June 15, 2008 DAP4	June 15, 2009 DAP6	June 15, 2009 DAP6	June 15, 2010 DAP7	Dec. 15, 2012 DAP8
III	- Rain rate (RR) - Advanced Quality Control Products	Dec. 15, 2008 DAP5	Dec. 15, 2008 DAP5	June. 15, 2010 DAP7	June 15, 2009 DAP6	June 15, 2010 DAP7	Dec. 15, 2012 DAP8

Table 1-4. MiRS product development phases and delivery timeline for products and sensors.

1.3. Product Access

Provide information that each user needs to obtain the data products intended for them. This includes the location of the data products and procedures for obtaining them. State the organizations and personnel who ensure maintenance and access. *(Document Object 36)*
Writers: PAL

State the procedures that should be followed for obtaining near real time (NRT) and archived product data files. This information may be in the developer's Operations Concept Document (OCD). Refer to the OCD in the developer's project artifact repository, if available. *(Document Object 46)*
Writers: PAL

MIRS operational products are generated in near-real time from the NOAA NPOESS Data Exploitation (NDE) for NPP ATMS products, and are made available to users through on the NDE data distribution server at ESPC for real-time users. For access to this server, information about data files, and associated documentation, the MiRS PAL should be contacted (see Table 1-2). In general, users are required to fill out the Data Access Request Form located on http://www.ospo.noaa.gov/Organization/About/access.html, and submits to nesdis.data.access@noaa.gov with a copy to the PAL.

The historical products are distributed for external users through the NOAA Comprehensive Large Array-data Stewardship System (CLASS) archive. Data can be queried and ordered from CLASS at the following web URL: http://www.class.noaa.gov. Registration with CLASS is required for ordering data. The actual data links are as follows:

http://gis.ncdc.noaa.gov/geoportal/catalog/search/resource/details.page?id=gov.noaa.ncdc:C00865
http://gis.ncdc.noaa.gov/geoportal/catalog/search/resource/details.page?id=gov.noaa.ncdc:C00866

MIRS experimental products are generated for all sensors (operational and research) on a daily basis at the NOAA Center for Satellite Applications and Research (STAR), by the product development team. These experimental products reflect the current status of the MIRS algorithm as it is developed toward the next DAP release to operations. Products, images, and validation statistics can be viewed at the password-protected web URL: http://www.star.nesdis.noaa.gov/smcd/mirs.
Login credentials may be obtained by contacting the MIRS product development lead listed above.

The output data set from processing a single NPP ATMS granule in the NDE environment is listed in the output Process Status File (PSF). This PSF file is generated after completion of MiRS processing, and lists all of the product files relevant to MiRS ATMS both for archiving and downstream processing (e.g. tailoring, MiRS QC DAP).

The PSF is located in the working directory specified in the PCF (Process Configuration File) defined by the production rules, and follows the naming convention "npp_scs_nde.PSF". The file is ASCII and should list 7 filenames as output, with their absolute path (likely in a sub directory in the working directory).

The 2 main output files are the product files in NetCDF4 format for imaging and sounding products. These products are used for tailoring and are also delivered to archive. Details about file attributes such as contents and size can be found at the end of this section.

Other output files are generated and listed in the PSF for downstream processing by the MiRS Quality Control (QC) DAP and should not be distributed to users. These include the binary “EDR” and “DEP” files, containing MiRS core and derived products, respectively; the binary “FMSDR” file containing the footprint matched or spatially averaged ATMS observations; and the ASCII “NEDT” files containing the computed noise values for each ATMS channel both before and after spatial averaging.

A summary with approximate file sizes for these output files produced from a single ATMS granule with start time “1359070” and end time “1359386” from June 30, 2012 is shown in Table 1-5.

Filename	Type	Size	Purpose
NEDT_SATMS_npp_d20120630_t1359070_e1359386_b03493_c20120630201602584086_noaa_ops_aftFM.dat	ASCII	779 K	Noise values for QC monitoring (before footprint matching)
NEDT_SATMS_npp_d20120630_t1359070_e1359386_b03493_c20120630201602584086_noaa_ops_befFM.dat	ASCII	779 K	Noise values for QC monitoring (after footprint matching)
FMSDR_TMS_npp_d20120630_t1359070_e1359386_b03493_c2012063020171226590 0_noaa_ops.h5.HR	Binary	307 K	Footprint matched observations for QC monitoring
EDR_TMS_npp_d20120630_t1359070_e1359386_b03493_c20120630201712265900_noaa_ops.h5.HR.ORB	Binary	4.3 M	1DVAR retrieval output for QC monitoring
DEP_TMS_npp_d20120630_t1359070_e1359386_b03493_c20120630201712265900_noaa_ops.h5.HR.ORB	Binary	257 K	Post-processing retrieval output for QC monitoring
NPR-MIRS-IMG_v9r0_NPP_s201206301359070_e201206301359386_c20120702150559.nc	NetCDF4	341 K	IMG product output for archive/tailoring
NPR-MIRS-SND_v9r0_NPP_s201206301359070_e201206301359386_c20120702150559.nc	NetCDF4	3.2 M	SND product output for archive/tailoring

Table 1-5. MiRS output files for downstream archive, tailoring, or QC DAP input.

Note: Only the NPR-MIRS-IMG and NPR-MIRS-SND product files are distributed to External Users.

For each input file to MIRS, (e.g. orbit, sub-orbit, granule), 2 output files containing the MIRS products are generated. These files are known as Environmental Data Records (EDRs) containing the MIRS core products and the Derived Environment Products (DEPs) containing integrated and post-processing products. *The files are internal formats to the MIRS algorithm and are only made available for experimental products through the STAR website mentioned above.* However, these EDR and DEP files are reformatted for dissemination to operational users.

For MIRS operational processing in the NDE environment of the current NPP ATMS sensor data, the MIRS EDR and DEP data is converted into 2 NetCDF4 formatted files to be archived at CLASS. The format adheres to the Climate and Forecast metadata convention. The MIRS sounding products are written to the “SND” prefixed file, while the imaging are written to the “IMG” prefixed file. The file naming convention follows:

NPR-MIRS-SND_vXrY_satID_sYYYYMMDDHHMMSSS_eYYYYMMDDHHMMSSS_cYYYYMMDDHHMMSSS.nc

and

NPR-MIRS-IMG_vXrY_satID_sYYYYMMDDHHMMSSS_eYYYYMMDDHHMMSSS_cYYYYMMDDHHMMSSS.nc

where:

vXrY - refers to the algorithm release or version number and subversion number,

satId – refers to the satellite name (e.g. NPP),

sYYYYMMDDHHMMSSS – refers to the granule or orbit start time year, month, day, hour, minute, second, and tenths of second,

eYYYYMMDDHHMMSSS – refers to the granule or orbit end time year, month, day, hour, minute, second, and tenths of second,

cYYYYMMDDHHMMSSS – refers to the MIRS output file creation time year, month, day, hour, minute, and tenths of second.

SND files for 1 NPP ATMS granule are approximately 3.3 MB in size, while IMG files are 350 KB. The contents for the SND and IMG files are described in Table 1-6 and Table 1-7, respectively.

Parameter Name	Dimension	Data Type/ (Scale Factor)	Explanation
Atm_type	Scanline x Field_of_view	I*16	0-simple scene, 1-retrieved scene
ChiSqr	Scanline x Field_of_view	R*32	Convergence metric
Freq	Channel	R*32	Instrument chan. central frequencies (GHz)
LZ_angle	Scanline x Field_of_view	R*32	Scene local zenith angle (degrees)
Latitude	Scanline x Field_of_view	R*32	Latitude (degrees)
Longitude	Scanline x Field_of_view	R*32	Longitude (degrees)
Orb_mode	Scanline x Field_of_view	I*16	0-ascending, 1-descending (orbit node)
PClw	Scanline x Field_of_view x P_Layer	R*32	Cloud liquid water profile (mm)
PGraupel	Scanline x Field_of_view x P_Layer	R*32	Graupel water profile (mm)
PIce	Scanline x Field_of_view x P_Layer	R*32	Ice water profile (mm)
PRain	Scanline x Field_of_view x P_Layer	R*32	Rain water profile (mm)
PSnow	Scanline x Field_of_view x P_Layer	R*32	Snow water profile (mm)
PTemp	Scanline x Field_of_view x P_Layer	R*32	Temperature Profile (K)
PVapor	Scanline x Field_of_view x P_Layer	R*32	Water vapor profile (g/kg)
Player	P_Layer	R*32	Pressure layer grid (hPa)
Plevel	P_Level	R*32	Pressure level grid (hPa)
Polo	Channel	I*16	Instrument chan. polarizations
Qc	Scanline x Field_of_view x Qc_dim	I*16	QC array: QC(0) 0-good, 1-use with caution, 2-bad
RAzi_angle	Scanline x Field_of_view	R*32	Relative Azimuth angle (degrees)
SZ_angle	Scanline x Field_of_view	R*32	Satellite Zenith angle (degrees)
ScanTime_UTC	Scanline x Field_of_view	R*64	Number of seconds since 00:00:00 UTC
ScanTime_dom	Scanline x Field_of_view	I*16	Scan time day of month
ScanTime_doy	Scanline x Field_of_view	I*16	Scan time day of year
ScanTime_hour	Scanline x Field_of_view	I*16	Scan time hour of day
ScanTime_minute	Scanline x Field_of_view	I*16	Scan time minute of hour
ScanTime_month	Scanline x Field_of_view	I*16	Scan time calendar month
ScanTime_second	Scanline x Field_of_view	I*16	Scan time second of minute

ScanTime_year	Scanline x Field_of_view	I*16	Scan time calendar year
Sfc_type	Scanline x Field_of_view	I*16	Surface classification
SurfP	Scanline x Field_of_view	I*16 (10)	Surface pressure value

Table 1-6. MIRS SND file contents, NetCDF4 format.

Parameter Name	Dimension	Data Type/ (Scale Factor)	Explanation
Atm_type	Scanline x Field_of_view	I*16	0-simple scene, 1-retrieved scene
BT	Scanline x Field_of_view x Channel	I*16 (100)	Corrected channel brightness temperature (K)
CLW	Scanline x Field_of_view	I*16 (100)	Integrated cloud liquid water (mm)
ChanSel	Scanline x Field_of_view x Channel	I*16	Channels used for retrieval
ChiSqr	Scanline x Field_of_view	R*32	Convergence metric
CldBase	Scanline x Field_of_view	I*16 (10)	Cloud base height (hPa)
CldThick	Scanline x Field_of_view	I*16 (10)	Cloud thickness (hPa)
CldTop	Scanline x Field_of_view	I*16 (10)	Cloud top height (hPa)
Emis	Scanline x Field_of_view x Channel	I*16 (10000)	Surface emissivity vector
Freq	Channel	R*32	Instrument center frequency (GHz)
GWP	Scanline x Field_of_view	I*16 (100)	Integrated graupel liquid water (mm)
IWP	Scanline x Field_of_view	I*16 (100)	Integrated ice liquid water (mm)
LWP	Scanline x Field_of_view	I*16 (100)	Integrated liquid (rain+cloud) water (mm)
LZ_angle	Scanline x Field_of_view	R*32	Local zenith angle (degrees)
Latitude	Scanline x Field_of_view	R*32	Latitude (degrees)
Longitude	Scanline x Field_of_view	R*32	Longitude (degrees)
Orb_mode	Scanline x Field_of_view	I*16	0-ascending, 1-descending (orbit node)
Polo	Channel	I*16	Instrument chan. polarizations
PrecipType	Scanline x Field_of_view	I*16	Precipitation type (frozen/liquid)
Qc	Scanline x Field_of_view x Qc_dim	I*16	QC array: QC(0) 0-good, 1-use with caution, 2-bad
RAzi_angle	Scanline x Field_of_view	R*32	Relative Azimuth angle (degrees)
RFlag	Scanline x Field_of_view	I*16	Rain flag
RR	Scanline x Field_of_view	I*16 (10)	Rain Rate (mm/h)
RWP	Scanline x Field_of_view	I*16 (100)	Integrated rain water (mm)
SFR	Scanline x Field_of_view	I*16 (100)	Snowfall Rate (mm/h)
SIce	Scanline x Field_of_view	I*16	Sea-ice Concentration (%)
SIce_FY	Scanline x Field_of_view	I*16	First-year SIC (%)
SIce_MY	Scanline x Field_of_view	I*16	Multi-year SIC (%)

SWE	Scanline x Field_of_view	I*16	Snow water equivalent (cm)
SWP	Scanline x Field_of_view	I*16 (100)	Integrated snow water (mm)
SZ_angle	Scanline x Field_of_view	R*32	Satellite zenith angle (degrees)
ScanTime_UTC	Scanline x Field_of_view	R*64	Number of seconds since 00:00:00 UTC
ScanTime_dom	Scanline x Field_of_view	I*16	Scan time day of month
ScanTime_doy	Scanline x Field_of_view	I*16	Scan time day of year
ScanTime_hour	Scanline x Field_of_view	I*16	Scan time hour of day
ScanTime_minute	Scanline x Field_of_view	I*16	Scan time minute of hour
ScanTime_month	Scanline x Field_of_view	I*16	Scan time calendar month
ScanTime_second	Scanline x Field_of_view	I*16	Scan time second of minute
ScanTime_year	Scanline x Field_of_view	I*16	Scan time calendar year
Sfc_type	Scanline x Field_of_view	I*16	Surface classification
Snow	Scanline x Field_of_view	I*16	Snow cover flag
SnowGS	Scanline x Field_of_view	I*16 (100)	Snow grain size (mm)
SurfM	Scanline x Field_of_view	I*16 (10)	Surface (soil) moisture
SurfP	Scanline x Field_of_view	I*16 (10)	Surface pressure value
TPW	Scanline x Field_of_view	I*16 (10)	Total precipitable water (mm)
TSkin	Scanline x Field_of_view	I*16 (100)	Skin temperature
WindDir	Scanline x Field_of_view	I*16 (100)	Wind direction (degrees)
WindSp	Scanline x Field_of_view	I*16 (100)	Wind speed (m/s)
WindU	Scanline x Field_of_view	I*16 (100)	Wind speed U vector (m/s)
WindV	Scanline x Field_of_view	I*16 (100)	Wind speed V vector (m/s)
YM	Scanline x Field_of_view x Channel	I*16 (100)	Uncorrected channel brightness temperature (K)

Table 1-7. MIRS IMG file contents, NetCDF4 format.

Note the contents of any collection level and granule level metadata provided to the archives per the Submission Agreement (SA) by the algorithm. This information should adhere to the NESDIS Data Center's best practice for metadata, specifically the ISO 19115-2 standards for Geographic information. Metadata content is worked in coordination with SA and the Data Center representative. Refer to the SA and coordinating guidance from the SPSRB *(Document Object 96)*
Writers: Development Lead and PAL should collaborate.

Each NetCDF4 file that is produced in the NDE environment and archived at CLASS contains a metadata header following the ISO 19115-2 standards and is based on the NDE-STAR metadata template. Table 1-8 shows the contents of the metadata header.

Parameter Name	Data Type	Explanation
Dimension Class		
Scanlines	I*32	Number of scanlines
Field_of_view	I*32	Number of fields of view
P_Layer	I*32	Number of vertical pressure layers
P_Level	I*32	Number of vertical pressure levels
Channel	I*32	Number of instrument channels
Qc_dim	I*32	Dimension of Quality Control array
Global Attributes		
missing_value	I*32	Value of missing data
cdf_version	R*64	NetCDF4 version
alg_version	I*32	Science algorithm version number
Conventions	String	NetCDF4 conventions version
Metadata_Conventions	String	Metadata conventions version
standard_name_vocabulary	String	Source of metadata vocabulary
project	String	Project name
title	String	Product name
summary	String	Description of products contained
date_created	String	File creation date/time
institution	String	Institution of file creator (processing center)
naming_authority	String	Domain of file creator
satellite_name	String	Satellite name products derived from
instrument_name	String	Instrument/sensor name products derived from
creator_name	String	Algorithm creator institution
creator_email	String	Algorithm creator email address
creator_url	String	Algorithm creator web url
publisher_name	String	Institution of data dissemination
publisher_email	String	Institution of data dissemination email
publisher_url	String	Institution of data dissemination web url
Metadata_Link	String	(optional/unused)
references	String	Algorithm documentation link
history	String	Algorithm history description
processing_level	String	Data processing level (e.g. Level II)
source	String	Input file name
time_coverage_start	String	Data coverage start time
time_coverage_end	String	Data coverage end time
cdm_data_type	String	Data type (e.g. Swath data)
geospatial_lat_units	String	Latitude units
geospatial_lon_units	String	Longitude units
geospatial_lat_resolution	I*4	Latitude resolution
geospatial_lon_resolution	I*4	Longitude resolution
geospatial_first_scanline_first_fov_lat	R*32	Latitude of first scanline/first FOV
geospatial_first_scanline_first_fov_lon	R*32	Longitude of first scanline/first FOV

geospatial_first_scanline_last_fov_lat	R*32	Latitude of first scanline/last FOV
geospatial_first_scanline_last_fov_lon	R*32	Longitude of first scanline/last FOV
geospatial_last_scanline_first_fov_lat	R*32	Latitude of last scanline/first FOV
geospatial_last_scanline_first_fov_lon	R*32	Longitude of last scanline/last FOV
geospatial_last_scanline_last_fov_lat	R*32	Latitude of last scanline/last FOV
geospatial_last_scanline_last_fov_lon	R*32	Longitude of last scanline/last FOV
total_number_retrievals	I*32	Total number of FOVs (scenes) in file
percentage_optimal_retrievals	R*32	Total percentage of optimal quality retrievals in file
percentage_suboptimal_retrievals	R*32	Total percentage of suboptimal quality retrievals in file
percentage_bad_retrievals	R*32	Total percentage of bad quality (failed) retrievals in file
id	String	Unique identifier for output data file

Table 1-8. Contents of the metadata header contained within the MIRS NetCDF4 SND and IMG product files.

2. ALGORITHM

This section will present an overview of the MIRS algorithm, required and supported input data and preprocessing, as well as required ancillary datasets, with a focus on S-NPP ATMS. More detailed information on the algorithm scientific basis can be found in the MIRS Algorithm Theoretical Basis Document.

2.1. Algorithm Overview

The MIRS is an iterative, physically-based retrieval system based on the One-Dimensional Variational Retrieval (1DVAR). It optimally extracts the information content present in the measurements. Retrievals are performed in a consistent fashion, with the end result being a set of consistent geophysical parameters, or Environmental Data Records (EDRs) that are computed simultaneously and, when used as inputs to the forward model, should nominally fit the measured radiances to within the noise level. The retrieval is performed in a reduced space by using Empirical Orthogonal Function (EOF) decomposition to allow a more stable inversion, a faster retrieval and to avoid the null space. The number of selected principal components is tuned for each instrument of interest.

The 1DVAR physical principle is to minimize a two-source cost function, composed of the departure of the simulated radiances from the actual measurements and the departure of the retrieved parameters from their respective backgrounds. In the retrieval scheme used by MIRS, the departure from the measured radiances is normalized by the noise level

(NEDT) impacting the measurements and the uncertainty in the forward modeling, making it possible to use the signal of a particular channel when the geophysical signature (through the derivative) is stronger than the noise (leading to a useful signal-to-noise level), and some other times dismiss the same channel when the signal in question is within the uncertainty/noise level. The departure from the background is also scaled by the uncertainty placed on the background. The source of these backgrounds could vary from simple climatology (loose background errors) to Numerical Weather Prediction (NWP) forecast fields (tight errors in the temperature background). Figure 2-1 summarizes the concept of MIRS.

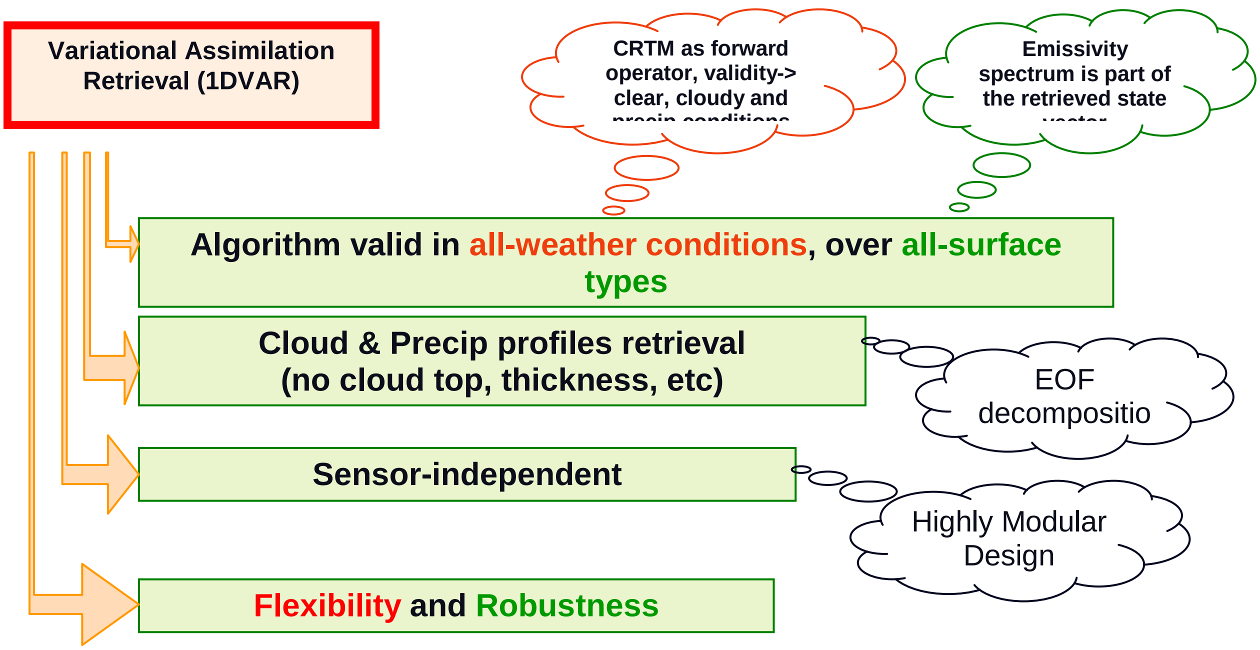

Figure 2-1. Concept characteristics of MIRS.

2.2. Input Satellite Data

2.2.1. Satellite Instrument Overview

High-level description of the satellite and instrument that provides the input data, including spectral (range, channels/bands), spatial (scan pattern, footprint), and other features (e.g., instrument noise). *(Document Object 29)*
Writers: Development Lead and PAL should collaborate

The S-NPP ATMS instrument is a cross-track passive microwave radiometer, with 22 channels covering a spectral range between 23 and 183 GHz. The instrument observes 96 fields-of-view (FOVs) across the scanline, with the lower resolution channels 1-16 being oversampled. More detail of the sensor characteristics is provided in Table 2-1.

Channel Number	Center Frequency (GHz)	Band width (MHz)	Sensitivity (NEDT) (K)	Accuracy (K)	Static beam width (MHz)
1	23.8	0.27	0.9	2.0	5.2
2	31.4	0.18	0.9	2.0	5.2
3	50.3	0.18	1.2	1.5	2.2
4	51.76	0.4	0.75	1.5	2.2
5	52.8	0.4	0.75	1.5	2.2
6	53.596±0.115	0.17	0.75	1.5	2.2
7	54.4	0.4	0.75	1.5	2.2
8	54.94	0.4	0.75	1.5	2.2
9	55.5	0.33	0.75	1.5	2.2
10	57.2903	0.33	0.75	1.5	2.2
11	57.2903±0.115	0.078	1.2	1.5	2.2
12	57.2903	0.036	1.2	1.5	2.2
13	57.2903±0.322	0.016	1.5	1.5	2.2
14	57.2903±0.322 ±0.010	0.008	2.4	1.5	2.2
15	57.2903±0.322 ±0.004	0.003	3.6	1.5	2.2
16	87-91(88.20)	2.0	0.5	2.0	2.2
17	164-167	3.0	0.6	2.0	1.1
18	183.31±7	2.0	0.8	2.0	1.1
19	183.31±4.5	2.0	0.8	2.0	1.1
20	183.31±3	1.0	0.8	2.0	1.1
21	183.31±1.8	1.0	0.8	2.0	1.1
22	183.31±1.0	0.5	0.9	2.0	1.1

Table 2-1. ATMS channels and passband characteristics.

MiRS is a product system operated within the NDE DHS by OSPO. MiRS uses data from the Advanced Technology Microwave Sounder (ATMS) instruments on the NPOESS Preparatory Project (NPP) platform. IDPS applies the instrument calibration and geolocation to generate the Science Data Records (SDR) and Temperature Data Record (TDR) files required by MiRS. NPP launched on October 28, 2011. It is in a sun synchronous circular orbit with a 10:30am descending-node orbit at an altitude of 824 km.

2.2.2. Satellite Data Preprocessing Overview

S-NPP ATMS data are pre-processed at the JPSS Interface Data Processing Segment (IDPS) at the NOAA Satellite Operations Facility (NSOF). The and made available to NDE and ESPC through the shared SAN managed through StoreNext.

The SDR and TDR are distributed from the IDPS and made available to NDE as 32 second granule files in HDF5 format. When NDE has the inputs required to process a CrIS and

ATMS granule set (based on the NUCAPS production rules), it executes the job to produce the output file described in this document.

Format information on the CrIS and ATMS SDR and TDR files is described in the NPOESS Common Data Format Control Book – External, Volume III – SDR/TDR Formats. The most recent versions of all the CDFCB documents can be obtained from the JPSS Program Office or from the NASA NPP site:
http://jointmission.gsfc.nasa.gov/science/documents.html

2.2.3. Input Satellite Data Description

Input satellite data is made available from various systems internal to NOAA for algorithm processing and product generation, such as the JPSS Interface Data Processing Segment (IDPS) for S-NPP ATMS. The same input satellite data is archived at and accessible from NOAA CLASS (http://www.class.noaa.gov) for download.

The S-NPP ATMS data Temperature Data Record (TDR), Sensor Data Record (SDR) and geolocation (GATMO) files are required for MIRS ATMS processing. The TDR provide the antenna temperatures, the SDR provide the warm target brightness temperatures for NEDT calculation, and the GATMO files contain geolocation and other metadata. This Level 1b data is provided in HDF5 format, following the NPOESS Common Data Format Control Books - External Volume III (CDFCB-X III) and can be accessed from:
http://jointmission.gsfc.nasa.gov/science/documents.html.

2.3. Input Ancillary Data

List each input file that contains ancillary data. Describe the ancillary data content of each file, either explicitly or by reference to the developer's design documents. This information may be in the developer’s Detailed Design Document (DDD). Refer to the DDD in the developer’s project artifact repository, if available. *(Document Object 32)*
Writers: Algorithm Scientists and Development Programmers should collaborate

There are no ancillary data required to run MiRS. However, analysis from GDAS and ECMWF are used for quality monitoring, and are required for the MiRS DAP.

3. PERFORMANCE

3.1. Product Testing

3.1.1. Test Data Description

Details of the data sets used for validation and verification as part of the code unit tests can be found in the following NOAA Enterprise Product Lifecycle (EPL) artifacts from the MiRS Test Readiness Review (TRR), the Code Unit Test Review (CUTR), and the System Readiness Review (SRR), which are located on the password-protected section of the MiRS website. Users should contact the algorithm developers for this information.

- http://www.star.nesdis.noaa.gov/smcd/mirs/meetings/meetingTRR20110119/MiRS_TRR_NPP_ATMS_2011-01-19_Final.pptx
- http://www.star.nesdis.noaa.gov/smcd/mirs/meetings/meeting20110526/MiRS_CUTR_NPP_ATMS_2011-05-26_Final.pptx
- http://www.star.nesdis.noaa.gov/smcd/mirs/meetings/meeting20120419/MiRS_SRR_NPP_ATMS_2012-04-19_Final.pdf

3.1.2. Unit Test Plans

Details of the software unit test plans can be found in the following NOAA Enterprise Product Lifecycle (EPL) artifacts from the MiRS Test Readiness Review (TRR), the Code Unit Test Review (CUTR), and the System Readiness Review(SRR), which are located on the password-protected section of the MiRS website. Users should contact the algorithm developers for this information.

- http://www.star.nesdis.noaa.gov/smcd/mirs/meetings/meetingTRR20110119/MiRS_TRR_NPP_ATMS_2011-01-19_Final.pptx
- http://www.star.nesdis.noaa.gov/smcd/mirs/meetings/meeting20110526/MiRS_CUTR_NPP_ATMS_2011-05-26_Final.pptx
- http://www.star.nesdis.noaa.gov/smcd/mirs/meetings/meeting20120419/MiRS_SRR_NPP_ATMS_2012-04-19_Final.pdf

3.2. Product Accuracy

3.2.1. Test Results

Details of the software code unit test results can be found in the following NOAA Enterprise Product Lifecycle (EPL) artifacts from the MiRS Test Readiness Review (TRR), the Code

Unit Test Review (CUTR), and the System Readiness Review (SRR), which are located on the password-protected section of the MiRS website. Users should contact the algorithm developers for this information.

- http://www.star.nesdis.noaa.gov/smcd/mirs/meetings/meetingTRR20110119/MiRS_TRR_NPP_ATMS_2011-01-19_Final.pptx
- http://www.star.nesdis.noaa.gov/smcd/mirs/meetings/meeting20110526/MiRS_CUTR_NPP_ATMS_2011-05-26_Final.pptx
- http://www.star.nesdis.noaa.gov/smcd/mirs/meetings/meeting20120419/MiRS_SRR_NPP_ATMS_2012-04-19_Final.pdf

3.2.2. Product Accuracy

Description of MIRS ATMS post-launch product validation activities were described in the Validation section. Table 2-1 summarizes the MiRS retrieval performance in terms of accuracy and precision for the official products, along with accuracy objectives. For some products (e.g. temperature and water vapor profiles) only selected layers are shown. For certain hydrometeor products (e.g. ice and rain water) a reliable reference data set is not available. However, the performance results for surface rain rate can be considered an indirect measure of the ice and rain water performances since the rain rate is derived directly from these products.

Further details and examples of validation results can be found at the official MiRS website `http://www.star.nesdis.noaa.gov/smcd/mirs/index.php`

Retrieval Product	Precision	Accuracy	Accuracy Specification
Temperature (300 mb), ocean (K)	1.9	0.7	1.
Temperature (300 mb), land (K)	1.6	0.7	1.5
Temperature (500 mb), ocean (K)	1.5	-0.4	1.
Temperature (500 mb), land (K)	1.5	-0.1	1.5
Temperature (900 mb), ocean (K)	2.2	1.2	2.0
Temperature (900 mb), land (K)	4.3	0.8	2.0
Water Vapor (300 mb), ocean (%)	53.	4.	20.
Water Vapor (300 mb), land (%)	56.	3.	20.
Water Vapor (500 mb), ocean (%)	51.	-6.	20.
Water Vapor (500 mb), land (%)	56.	18.	20.
Water Vapor (900 mb), ocean (%)	20.	-3.	20.
Water Vapor (900 mb), land (%)	34.	-4.	20.
Total Precipitable Water, ocean (mm)	2.5	1.5	1.0
Total Precipitable Water, land (mm)	2.2	1.7	2.5
Cloud Liquid Water, ocean (mm)	0.10	-0.03	0.03
Land Surface Temperature (K)	7.0	3.0	4.0
Emissivity (23.8 GHz Vpol), land	0.02	0.01	0.020
Emissivity (50.3 GHz Hpol), land	0.03	0.01	0.015
Emissivity (165.5 GHz Hpol), land	0.04	0.01	0.015
Rain Rate, ocean (mm/h)	0.5	0.05	0.10
Rain Rate, land (mm/h)	0.5	0.03	0.05
Sea Ice Concentration (%)	15.0	-5.0	10.0
Snow Water Equivalent (cm)	5.0	-2.0	3.0

Table 3-1. Summary of MiRS ATMS product performance based on validation activities. Unless otherwise stated, results are for combined clear/cloudy conditions.

3.3. Product Quality Output

Currently, two methods of quality assessment are generated in the 1DVAR algorithm and produced in the output files. These include the convergence metrics and the quality control structure. Three other measures are works in progress and will be included in future quality monitoring: the uncertainty matrix, contribution functions and average kernel.

The convergence metrics currently provided consist of the chi square (χ^2) and the forward operator Y^{fwd}. The χ^2 is the root-mean-square (rms) of the residuals between the measure brightness temperatures and those simulated with Y^{fwd}, and are considered acceptable when less than or equal to 1. If above 1, the retrievals are considered to be of unacceptable quality. It is possible for users to raise this convergence metric to be acceptable up to a value of 5 if necessary. However, any χ^2 above 5 is always of unacceptable quality.

The quality control structure contains four specific sections. It is stored as four words, sixteen bits each. Figure 3-1 illustrates the full definition of each quality control section. The first word, denoted QC(1), represents general validity control and has three settings. A value of 0 is assigned for acceptable MiRS products at the location in question. A value of 1 stands for problematic products, further details given in the other words. A value of 2 means the MiRS products are the results of bad or untrusted retrievals.

The first 6 bits of the QC(2) word pertains to the overall convergence of the retrievals and whether precipitation of any degree was present or not. Its later bits also contain a set of "out-of-bound" flags for the various retrieved products. The first set of bits determine if the QC(1) is denoted as problematic, and the second set whether the retrieval is bad. The QC(3) word has a similar structure. Its first 6 bits are related to the temperature lapse rate and humidity aspects, among others. These bits likewise will set QC(1) as problematic if triggered. Its second set of bits refer to validity flags for the retrieved products, and will set QC(2) to bad if triggered. QC(4) is devoted entirely to measurement quality and surface type. It will automatically set QC(1) to represent bad retrievals if there is any problem.

The QC structure is provided in both the EDR and DEP files, and both will be mostly identical. The QC provided in the DEP file may be different for some bits that are related to the post-processing of the derived products, and any additional information obtained therein.

	Bit 0	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	Bit 9	Bit 10	Bit 11	Bit 12	Bit 13	Bit 14	Bit 15
QC (1)	0 = GOOD, 1= SOME PROBLEM, 2=BAD															
QC (2)	CONVERGENCE I (ChiSq >= 10)	CONVERGENCE II (5<=ChiSq <10)	PRECIPITATION (YES/NO)	TYPE OF PRECIPITATION			OUT-OF-BOUND FLAGS								MEAS. QC	
				LIGHT	MEDIUM	HEAVY	TSKIN	TEMP	Q	EMISS	TPW	ICLW	RWP	GWP		
QC (3)	TEMPERATURE LAPSE RATE	TEMPERATURE INVERSION (Range:Psfc-200mb to Psfc)	SUPERSATURATION (RH > 99.9 %)	SUPERSATURATION 3 CONTIGUOUS LAYERS (RH > 99.9 %)	HUMIDITY INVERSION	CLOUD	VALIDITY FLAGS									
							TSKIN	TEMP	Q	EMISS	TPW	ICLW	RWP	GWP		
QC (4)	ALLOCATED FOR EACH ELEMENT OF MEASUREMENT QC												OCEAN	LAND		Calibration

Figure 3-1. Quality control structure definitions.

3.4. External Product Tools

MiRS data are in netCDF4 format, and can be read and processed with any public available netCDF tools. There no particular tools are provided from the MiRS team. External users can choose their own tools to display and analyze these output files.

4. PRODUCT STATUS

4.1. Operations Documentation

The NDE MiRS is running under the NDE frame work, and operated under “NDE Operations Handbook Version 1.0 (2013)”. OSPO ESPS operation tracks any changes made to the NDE system. The MiRS operational team keeps an Operational Event Log to track any changes made to science, instruments, and the MiRS system at high description level. Detailed changes are tracked under the Configuration Management system. Usual references can be referred to the NDE MiRS System Maintenance Manual, NDE Operations Handbook Version, and NDE MiRS Algorithm Theoretical Basis Document.

4.2. Maintenance History

The NDE MiRS System Maintenance Manual (SMM) will be updated to reflect the changes that will be required to maintain the MiRS system within the ESPC environment. Information regarding the changes to the products is tracked by the Operational Event Log and will be available to users upon request. Product metadata will be updated as per the changes required in the product including the version number, quality flags etc.

END OF DOCUMENT