



Multiangle SpectroPolarimetric Imager

Data Product Specification for the AirMSPI Level 1B2 Products (V005)

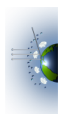
David J. Diner (PI)
Michael J. Garay
Felix C. Seidel
Carol J. Bruegge
Veljko M. Jovanovic
Michael A. Bull
Irina N. Tkatcheva
Brian E. Rheingans
Gerard van Harten
Abigail M. Nastan
Earl G. Hansen

Corresponding author: Michael.J.Garay@jpl.nasa.gov



Jet Propulsion Laboratory
California Institute of Technology

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Airborne Multiangle SpectroPolarimetric Imager (AirMSPI)

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APPROVALS:

David J. Diner

AirMSPI Principal Investigator

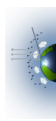
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Approval signatures are on file with the AirMSPI Project.

To determine the latest released version of this document, consult the AirMSPI web site (<http://airbornescience.jpl.nasa.gov/instruments/airmspi/>).

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Document Change Log

Revision	Date	Affected Portions and Description
	3 December 2013	Original release for V003
A	11 April 2014	Updated for V004: RDQI, other
B	5 February 2018	Updated for V005: elevation and land water mask, other

Which Product Versions Does this Document Cover?

Product Filename Prefix	Version Number in Filename	Brief Description
AirMSPI_ER2_GRP_ELLIPSOID	V005	L1B2 Ellipsoid-Projected Georectified Radiance and Polarization Data
AirMSPI_ER2_GRP_TERRAIN	V005	L1B2 Terrain-Projected Georectified Radiance and Polarization Data

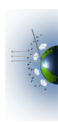
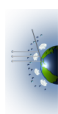


TABLE OF CONTENTS

1	INTRODUCTION	1
1.1	AIRMSPI L1B2 PRODUCTS.....	1
1.2	AIRMSPI DATA PRODUCTS.....	1
1.3	CONTROLLING DOCUMENTS.....	1
1.4	RELATED DOCUMENTS.....	1
2	AIRMSPI LEVEL 1B2 DATA PRODUCT SPECIFICATION.....	2
2.1	AIRMSPI LEVEL 1B2 PRODUCT GRANULE BRIEF DESCRIPTION.....	2
2.2	AIRMSPI LEVEL 1B2 PRODUCT GRANULE COMPONENTS	2
2.3	AIRMSPI LEVEL 1B2 PRODUCT	3
2.3.1	<i>Granule Metadata Description (.met File).....</i>	<i>3</i>
2.3.2	<i>HDF-EOS-5 Format Description.....</i>	<i>4</i>
3	APPENDIX.....	10
	ACRONYM LIST	10



1 INTRODUCTION

1.1 *AirMSPI L1B2 PRODUCTS*

The Airborne Multiangle SpectroPolarimetric Imager (AirMSPI) Level 1B2 products contain radiometric and polarimetric observations of clouds, aerosols, and the surface of the Earth made from the National Aeronautics and Space Administration's (NASA) ER-2 high altitude research aircraft. The AirMSPI instrument acquires data using one of two possible modes, step-and-stare and sweep. Step-and-stare data are gridded with 10 m spatial sampling, with one file provided for each view angle. Sweep data are gridded with 25 m spatial sampling. Files are distributed in HDF-EOS-5 format.

1.2 *AirMSPI DATA PROCESSING AND DISTRIBUTION*

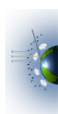
The Multi-angle Imaging SpectroRadiometer (MISR) Science Computing Facility (SCF) at the Jet Propulsion Laboratory (JPL) supports the development of AirMSPI science algorithms and software, instrument calibration and performance assessment, and also provides quality assessment and data validation services with respect to AirMSPI Science Data Processing (SDP). The MISR SCF is used to perform the standard processing of the AirMSPI data. After AirMSPI data processing is complete, the standard output products are archived and made available to users via the Langley Research Center (LaRC) Atmospheric Science Data Center (ASDC) client services. See https://eosweb.larc.nasa.gov/project/airmspi/airmspi_table.

1.3 *CONTROLLING DOCUMENTS*

- 1) Multiangle Spectropolarimetric Imager (MSPI) Algorithm Theoretical Basis Document Rev. B Draft, November 2009 (or latest version).

1.4 *RELATED DOCUMENTS*

- 1) User Guide for the AirMSPI Level 1B2 Products, JPL D-78962, April 2014 (or latest version).



2 AirMSPI LEVEL 1B2 DATA PRODUCT SPECIFICATION

2.1 AirMSPI LEVEL 1B2 PRODUCT GRANULE BRIEF DESCRIPTION

The AirMSPI L1B2 Product contains radiance information in eight spectral bands (nominally 355, 380, 445, 470, 555, 660, 865, and 935 nm) as well as polarimetric information in three of these bands (470, 660, 865 nm) – representing 14 total channels. Quality indicators, solar and view geometry, and temporal information associated with the acquired imagery are provided, as well as geolocation (latitude and longitude) and geographic (elevation, land-water mask) information.

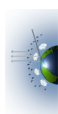
2.2 AirMSPI LEVEL 1B2 PRODUCT GRANULE COMPONENTS

Each granule of the AirMSPI L1B2 Product corresponds to a single data acquisition: a single stare in a step-and-stare sequence or a single sweep (forward or aftward). Each file uses the HDF-5 General Cartographic Transformation Package (GCTP) Universal Transverse Mercator (UTM) grid format at either 10 m (step-and-stare) or 25 m (sweep) spatial sampling. Table 1 shows some example product file names and describes the naming conventions.

Table 1 – L1B2 Example Product Files and Grid

COLLECTION (Shortname)	Local Granule ID ¹
AirMSPI_PODEX_GRP_Data	AirMSPI_ER2_GRP_ELLIPSOID_yyyymmdd_hhmmssZ_tttt_aaa[A,N,F]_Fff_Vvvv.hdf and/or AirMSPI_ER2_GRP_TERRAIN_yyyymmdd_hhmmssZ_tttt_aaa[A,N,F]_Fff_Vvvv.hdf

¹ Where yyyy is the year, mm is the month, dd is the day, hh is the hour, mm is the minute, ss is the second in UTC of the central observation, tttt corresponds to the target name, aaa is the view angle, A is aftward, N is nadir, F is forward, Fff is the file format version, and Vvvv is the version number. For a step-and-stare image, the view angle aaa is reported to the nearest tenth of a degree × 10, whereas SWP is reported for a sweep image.

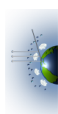


2.3 AirMSPI LEVEL 1B2 PRODUCT

2.3.1 Granule Metadata Description (.met file)

Table 2 – Metadata (.met)

Field Name	Definition	Example Contents
DatasetName	Name of dataset	AirMSPI_PODEX_Ellipsoid-projected_Georegistered_Radiance_Data
GranuleName	Name of specific data granule	AirMSPI_ER2_GRP_ELLIPSOID_20130114_210928Z_CA-SanDiegoCounty_000N_F01_V005.hdf
StartDate	UTC date at start of data acquisition for this granule (yyyy-mm-dd)	2013-01-14
StartTime	UTC time at start of data acquisition for this granule (hh:mm:ss.sssssZ)	21:09:03.998154Z
EndDate	UTC date at end of data acquisition of this granule (yyyy-mm-dd)	2013-01-14
EndTime	UTC time at end of data acquisition for this granule (hh:mm:ss.sssssZ)	21:09:53.104616Z
MaxLat	Maximum geographic latitude of data in this granule (degrees N)	32.999765
MaxLon	Maximum geographic longitude of data in this granule (degrees E)	-117.142285
MinLat	Minimum geographic latitude of data in this granule (degrees N)	32.675452
MinLon	Minimum geographic longitude of data in this granule (degrees E)	-117.526453
FlightHeadingAzimuth	Mean aircraft heading for data in this granule (degrees relative to N)	242.2
GranuleSize	Size of data granule (bytes)	308871041
Processing Date-Time	UTC date and time of data processing (yyyy-mm-ddThh:mm:ssZ)	2016-03-29T20:24:18Z
VersionID	Product version number	005
Browse	Indicates existence of .jpeg browse product	Y
Browsjpeg	Filename of .jpeg browse product	AirMSPI_ER2_GRP_ELLIPSOID_20130114_210928Z_CA-SanDiegoCounty_000N_F01_V005.jpg
jpegsize	Size of .jpg browse product (bytes)	448957
Browskml	Name of associated Google Earth KML file	AirMSPI_ER2_MAP_INFO_ELLIPSOID_20130114_210928Z_CA-SanDiegoCounty_V005.kml
kmlsize	Size of .kml Google Earth file (bytes)	599860
Resolution	Pixel resolution of data in granule (meters)	10.0
TargetType	Text description of target type for this	Ocean



	granule	
GeolocationStage	Level of geolocation processing for this granule (Direct or Indirect)	Indirect
GeoPolygon	Latitude/longitude coordinate pairs describing location of data within granule	((32.890972,-117.306803),(32.849439,-117.286755),...)

2.3.2 HDF-EOS-5 Format Description (.hdf file)

HDF-EOS-5 files are organized into groups and subgroups. The tables below describe the content of an AirMSPI HDF-EOS-5 file in a manner consistent with this organization.

Table 3 – Top Level Contents

Field Name	Description
Channel_Information	Contains information about the AirMSPI spectral channels and solar constant values
HDFEOS	Contains the primary data contents of the file
HDFEOS INFORMATION	Contains ancillary information (metadata) about the file

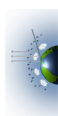
Table 4 – Channel_Information Contents

Field Name	Description
Center_wavelength	Measured central wavelength (in nm) for each AirMSPI spectral channel
Channel_name	AirMSPI channel designation; channel names ending with I are radiometric channels, channel names ending with Q or U are polarimetric channels
Channel_number	Field that maps HDF index (0–13) to numerical channel number (1–14)
Effective_bandwidth	Bandwidth (in nm) of a rectangular filter having the same area as the original spectral response function (SRF) as determined by a moments analysis for each AirMSPI spectral channel – the original SRF has a peak value of one
Effective_transmittance	The transmittance (in the range from 0 to 1) of a rectangular filter having the same area as the actual SRF for each AirMSPI spectral channel
Solar_irradiance_at_1_AU	The extraterrestrial solar irradiance (in $W\ m^{-2}\ nm^{-1}$) weighted by the total-band spectral response function for each channel at the nominal Earth-Sun distance (1 AU)

Table 5 – HDFEOS Contents

Field Name	Description
ADDITIONAL	Contains additional information useful to users of the L1B2 data products
GRIDS	Contains the gridded HDF-EOS data

Table 6 – HDFEOS/ADDITIONAL Contents



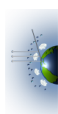
Field Name	Description
FILE_ATTRIBUTES	Contains additional information useful to users of the L1B2 data products

Table 7 – HDFEOS/ADDITIONAL/FILE_ATTRIBUTES Contents

Field Name	Description
Band Table	Provides the band number (1-8) and the associated band name
GeoPolygon	Latitude/longitude coordinate pairs describing location of data within granule

Table 8 – HDFEOS/ADDITIONAL/FILE_ATTRIBUTES Attributes Contents

Field Name	Description
Acquisition end time	UTC date and time of end of data acquisition
Acquisition start time	UTC date and time of start of data acquisition
Aircraft heading (degrees)	Mean aircraft heading during data acquisition (relative to North)
BRF equation	Equation used to convert radiance to at-altitude bidirectional reflectance factor (BRF) $\text{BRF} = \text{Radiance} \times \pi \times \text{sun_distance}^2 \times (1/\text{solar_irradiance}) \times [1/\cos(\text{sun_zenith})]$
Epoch (UTC)	UTC time used as the reference epoch for this data granule
Geolocation stage	Level of geolocation processing for this granule (Direct or Indirect)
Gimbal angle average (degrees)	Average gimbal angle for this data granule
Gimbal angle maximum (degrees)	Maximum gimbal angle for this data granule
Gimbal angle minimum (degrees)	Minimum gimbal angle for this data granule
Gimbal scan direction	Direction of gimbal scan (forward or aftward)
Lower left latitude	Geographic latitude of data in the lower left corner of the granule (degrees N)
Lower left longitude	Geographic longitude of data in lower left corner of the granule (degrees E)
Lower right latitude	Geographic latitude of data in the lower right corner of the granule (degrees N)
Lower right longitude	Geographic longitude of data in the lower right corner of the granule (degrees E)
Production time	UTC date and time of product generation
Radiance units	Units of radiance data reported in the product ($\text{W m}^{-2} \text{sr}^{-1} \text{nm}^{-1}$)
Resolution	Pixel resolution of data in product (m)
Sun distance	Earth-Sun distance for use in calculation of BRF (AU)
Target type	Text description of target type for this granule
Upper left latitude	Geographic latitude of data in the upper left corner of the granule (degrees N)
Upper left longitude	Geographic longitude of data in upper left corner of the granule (degrees E)
Upper right latitude	Geographic latitude of data in the upper right corner of the granule (degrees N)
Upper right longitude	Geographic longitude of data in the upper right corner of the granule (degrees E)



[config]	Configuration parameters used in data processing
[history]	Processing history information
[input]	Input information used in data processing
granule_id	ID name for this data granule

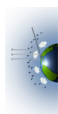
Table 9 – HDFEOS/GRIDS Contents

Field Name	Description
355nm_band	Parameters associated with the 355 nm (UV) spectral channel (I)
380nm_band	Parameters associated with the 380 nm (UV) spectral channel (I)
445nm_band	Parameters associated with the 445 nm (VIS) spectral channel (I)
470nm_band	Parameters associated with the 470 nm (VIS) polarized spectral channels (I, Q, and U)
555nm_band	Parameters associated with the 555 nm (VIS) spectral channel (I)
660nm_band	Parameters associated with the 660 nm (VIS) polarized spectral channels (I, Q, and U)
865nm_band	Parameters associated with the 865 nm (NIR) polarized spectral channels (I, Q, and U)
935nm_band	Parameters associated with the 935 nm (NIR) spectral channel (I)
Ancillary	Ancillary geographic information.
XDim	UTM projection X coordinate (see note after Table 10)
YDim	UTM projection Y coordinate (see note after Table 10)

Note: Each Field at the HDFEOS/GRIDS level, with the exception of XDim and YDim, contains its own *Data Fields* Subdirectory described below

Table 10 – HDFEOS/GRIDS/Data Fields Contents for Unpolarized Spectral Channels

Field Name Parameter Description	Dimension List	Number Type	Units	Flag Values
Step-and-stare (Spatial Sampling: 10 m x 10 m, e.g. XDim = 3584, YDim = 3584) Sweep (Spatial Sampling: 25 m x 25 m, e.g. XDim = 3584/4608, YDim = 2048/3072)				
Glint_angle The angle between the vector pointing in the direction of specularly reflected direct sunlight from a horizontal surface and the vector pointing toward the instrument	XDim YDim	FLOAT32	Degrees	FillValue = -999.0
I Radiance	XDim, YDim	FLOAT32	W m ⁻² sr ⁻¹ nm ⁻¹	FillValue = -999.0
I.mask Indicates locations with valid data	XDim, YDim	INT32	None	0 = Not valid 1 = Valid
RDQI Radiometric Data Quality Indicator	XDim, YDim	FLOAT32	None	0 = Within specifications 1 = Reduced accuracy 2 = Not usable for science 3 = Unusable for any



				purpose
Scattering_angle The angle between the vector pointing in the direction of direct sunlight and the vector pointing toward the instrument	XDim YDim	FLOAT32	Degrees	FillValue = -999.0
Sun_azimuth Angle measured clockwise relative to local North of the projection of the solar illumination vector onto a horizontal plane. The illumination vector points in the direction of photon travel. Note that for a vector pointing <i>toward</i> the position of the Sun in the sky the azimuth relative to local North is given by [(Sun_azimuth + 180°) mod 360°]	XDim, YDim	FLOAT32	Degrees	FillValue = -999.0
Sun_zenith Solar zenith angle relative to overhead sun (0°)	XDim, YDim	FLOAT32	Degrees	FillValue = -999.0
Time_in_seconds_from_epoch Time in seconds from the epoch	XDim, YDim	FLOAT64	Seconds	FillValue = -999.0
UTM_projection Universal Transverse Mercator projection information*	1	CHAR8	See footnote*	
View_azimuth Angle measured clockwise relative to local North of the projection of the view vector onto a horizontal plane. The view vector points in the direction of photon travel.	XDim, YDim	FLOAT32	Degrees	FillValue = -999.0
View_zenith View zenith angle relative to nadir (0°)	XDim, YDim	FLOAT32	Degrees	FillValue = -999.0
XDim UTM projection x coordinate*	XDim	FLOAT64	Meters	
YDim UTM projection y coordinate*	YDim	FLOAT64	Meters	

*UTM projection defines a horizontal coordinate transform, using NetCDF style attributes attached to a single byte placeholder variable. The UTM information is contained in the UTM_projection attributes, which are: inverse_flattening, semi_major_axis, transform_name, and utm_zone_number. The UTM information is identical for each band and is provided for compatibility with mapping software.

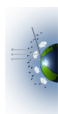


Table 11 – Additional HDFEOS/GRIDS/Data Fields Contents for Polarized Spectral Channels

Field Name Parameter Description	Dimension List	Number Type	Units	Flag Values
Step-and-stare (Spatial Resolution: 10 m x 10 m, e.g. XDim = 3584, YDim = 3584)				
Sweep (Spatial Resolution: 25 m x 25 m, e.g. XDim = 3584/4608, YDim = 2048/3072)				
AOLP_meridian Angle of linear polarization (AOLP) relative to the meridian plane (the plane containing the observed beam and the z-axis of the surface) $AOLP = 0.5 \tan^{-1} \left(\frac{U}{Q} \right)$	XDim, YDim	FLOAT32	Degrees	FillValue = -999.0
AOLP_scatter AOLP relative to the scattering plane (the plane containing the incident beam and the scattered beam)	XDim, YDim	FLOAT32	Degrees	FillValue = -999.0
DOLP Degree of linear polarization (DOLP) $DOLP = \sqrt{\left(\frac{Q}{I}\right)^2 + \left(\frac{U}{I}\right)^2}$	XDim, YDim	FLOAT32	None (Range 0.0 – 1.0)	FillValue = -999.0
IPOL The polarized radiance = I × DOLP	XDim YDim	FLOAT32	W m ⁻² sr ⁻¹ nm ⁻¹	FillValue = -999.0
Q.mask Indicates locations with valid Q data	XDim, YDim	INT32	None	0 = Not valid 1 = Valid
Q_meridian Q Stokes parameter relative to the meridian plane	XDim, YDim	FLOAT32	W m ⁻² sr ⁻¹ nm ⁻¹	FillValue = -999.0
Q_scatter Q Stokes parameter relative to the scattering plane	XDim, YDim	FLOAT32	W m ⁻² sr ⁻¹ nm ⁻¹	FillValue = -999.0
U.mask Indicates locations with valid U data	XDim, YDim	INT32	None	0 = Not valid 1 = Valid
U_meridian U Stokes parameter relative to the meridian plane	XDim, YDim	FLOAT32	W m ⁻² sr ⁻¹ nm ⁻¹	FillValue = -999.0
U_scatter U Stokes parameter relative to the scattering plane	XDim, YDim	FLOAT32	W m ⁻² sr ⁻¹ nm ⁻¹	FillValue = -999.0

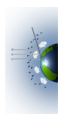


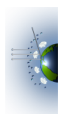
Table 12 – HDFEOS/GRIDS/Data Fields Contents for Ancillary Data

Field Name Parameter Description	Dimension List	Number Type	Units	Flag Values
Step-and-stare (Spatial Resolution: 10 m x 10 m, e.g. XDim = 3584, YDim = 3584)				
Sweep (Spatial Resolution: 25 m x 25 m, e.g. XDim = 3584/4608, YDim = 2048/3072)				
Elevation Surface elevation at the reported latitude and longitude relative to the World Geodetic System (WGS) 84 ellipsoid.*	XDim, YDim	FLOAT64	Meters	FillValue = -999.0
Land_water_mask Mask indicating the presence of land (1) or water (0)	XDim, YDim	INT32	None	FillValue = -999.0
Latitude Geographic Latitude	XDim, YDim	FLOAT64	Degrees North	FillValue = -999.0
Longitude Geographic Longitude	XDim, YDim	FLOAT64	Degrees East	FillValue = -999.0
UTM_projection Universal Transverse Mercator projection information	1	CHAR8	See note after Table 10	
XDim UTM projection x coordinate	XDim	FLOAT64	Meters	
YDim UTM projection y coordinate	YDim	FLOAT64	Meters	

*Note that the surface elevation is not necessarily the altitude to which the AirMSPI data are projected (e.g., in the Ellipsoid product, the projection altitude is always the WGS84 ellipsoid).

Table 13 – HDFEOS INFORMATION Contents

Field Name	Description
StructMetadata.0	Structural metadata for the file. This is ancillary information regarding the HDF-EOS contents of the grids within the file, including field names, dimensions, and data types, in a human readable format.
StructMetadata.1	Continuation of the structural metadata.



3 Appendix

Acronym List

AirMSPI.....	Airborne Multiangle SpectroPolarimetric Imager
AOLP.....	Angle of Linear Polarization
ASDC.....	Atmospheric Science Data Center
AU.....	Astronomical Unit
BRF.....	Bidirectional Reflectance Factor
DOLP.....	Degree of Linear Polarization
EOS.....	Earth Observing System
GCTP.....	General Cartographic Transformation Package
HDF-EOS.....	Hierarchical Data Format for EOS
JPL.....	Jet Propulsion Laboratory
LaRC.....	Langley Research Center (NASA)
MISR.....	Multi-angle Imaging SpectroRadiometer
NASA.....	National Aeronautics and Space Administration
NetCDF.....	Network Common Data Form
NIR.....	Near Infrared PODEX Polarimeter Definition EXperiment
SCF.....	Science Computing Facility
SDP.....	Science Data Processing
SRF.....	Spectral Response Function
UTC.....	Coordinated Universal Time
UTM.....	Universal Transverse Mercator
UV.....	Ultraviolet
VIS.....	Visible
WGS84.....	World Geodetic System 1984

