National Aeronautics and Space Administration
Goddard Earth Science Data Information and Services Center (GES DISC)

Earth Observing System (EOS)

Atmospheric InfraRed Sounder (AIRS)

Level 1C Data Product User Guide

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Product Version 6.7

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Revision History

Product Version	***Software Version***	***Date***	***Changes***
6.7	6.7.2	2020-02-26	Initial Release

Table of Contents

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

1.0 Introduction

This document provides basic information about Version 6.7 of the Atmospheric InfraRed Sounder (AIRS) Level 1C (L1C) product. The AIRS instrument is on the EOS-Aqua spacecraft.

The AIRS Level 1C product consists of calibrated radiances which have been processed beyond Level 1B to correct for select AIRS instrument characteristics, including spectral gaps, spectral overlaps, bad channels, co-registration errors, and wavenumber drift.

The AIRS Level 1B product is not described in detail in this document.

1.1 Mission Description

The NASA EOS-Aqua satellite was launched on May 4, 2002 from Vandenberg Air Force Base in California into an orbit with an altitude of 705 km above the Earth surface, an inclination angle of 98.2 deg and a 13:35:45 +/- 00:00:45 local time ascending node. The Aqua spacecraft is part of the "A-train" or "afternoon constellation". The Aqua mission collects information about the Earth's water cycle, including evaporation from the oceans, water vapor in the atmosphere, clouds, precipitation, soil moisture, sea ice, land ice, and snow cover on the land and ice. Additional variables also being measured by Aqua include radiative energy fluxes, aerosols, vegetation cover on the land, phytoplankton and dissolved organic matter in the oceans, and air, land, and water temperatures.

1.2 AIRS Instrument Description

The Atmospheric Infrared Sounder (AIRS) is designed to measure temperature and water vapor profiles, trace gas concentrations, cloud properties and radiation balance using infrared wavelengths. AIRS is a grating array spectrometer having 2378 channels sensitive in the range 3.7 to 15.4 microns. The spectral resolution ($\lambda/\Delta\lambda$) is about 1200. A combination of a design philosophy having radiometric accuracy as a foremost goal, cooled and temperature-controlled spectrometer hardware (including most of the optics), and a thorough pre-flight and in-orbit calibration have made AIRS a superb instrument that produces very accurate and stable radiance data (Pagano 2018, Aumann 2019).

This Level 1C product was produced using version 5 of the AIRS Level 1B product, AIRIBRAD_005 https://disc.gsfc.nasa.gov/datacollection/AIRIBRAD_005.html.

1.3 Product History

Version 5.0 AIRS Level 1B is the basis for v6.x Level 1C products. It calibrates the 2378 instrument channels and reports measured radiances for each one at whatever channel center wavenumbers the instrument is currently sensing.

Version 6.1 Level 1C was the first Level 1C product in limited release. It changed the channel set to 2645 channels in monotonically increasing order (Aumann 2020, Section 3) and synthesized radiances for channels in spectral gaps and channels with dead detectors or excessive noise (Aumann 2020, Section 2).

Version 6.7 is the first AIRS Level 1C product in full release. In addition to the features of v6.1 L1C, v6.7 also adjusts the radiances to compensate for changes in channel center frequency (Aumann 2020, Section 4).

1.4 Data Disclaimer

Version 6.7 AIRS Level 1C data are released to the public as is. Every effort has been made to properly represent the data which this document describes. The AIRS Project assumes no responsibility for science results arising from the use of this data.

See Section 3.6 below for known issues.

1.5 Where to find the AIRS L1C data

The AIRS Level 1C product can be found at and downloaded from the Goddard Distributed Active Archive Center (GDAAC). There you will find additional information and documentation about this product and other products of interest. Search "AIRICRAD" under Data Collections.

See section 5.0 for details.

1.6 Referencing the AIRS L1C data

In a publication, the source of the AIRS L1C data should be stated as:

> AIRS Project (2019), AIRS/Aqua L1C Infrared (IR) resampled and corrected radiances V6.7, GES DISC, Accessed: **[*Data Access Date*]** 10.5067/VWD3DRC07UEN

1.7 Contact Information

For information, questions or concerns with this AIRS Level 1C data set, please send your questions to: askairs@jpl.nasa.gov.

2.0 AIRS Level 1C Product Overview

The AIRS Level 1C product is generated using v5.0 L1B data that has been processed by the Earth Observing System (EOS) Data and Operations System (EDOS) located at NASA's Goddard Earth Sciences Data and Information Services Center (GES DISC).

The AIRS Level 1C product consists of calibrated and corrected radiances and geolocation along with any metadata necessary to use and interpret this product.

2.1 Product Granulation and Identification

The AIRS product is divided into a series of 6-minute segments or granules with each granule making up one file and 240 granules per day. For each day, each 240 files are identified by granule number in the filename.

The nominal start time of granule 1 would be T00:06:00 if there were no leap seconds. The actual start time is earlier than that by the number of leap seconds between 1958 and the data time. It is T00:05:26 for data at the start of the mission in 2002 and T00:05:21 for data from 2019.

The ability to uniquely identify a granule is built in to the AIRS L1C product. The first part of the file name is AIRS.yyyy.mm.dd.ggg, with the year, month, day, and granule number. See section 2.7.

2.2 Algorithm Background

The AIRS L1C data products are a result of processing NASA Level 0 data through Level 1A/Geolocation, Level 1B, and Level 1C. See Figure 2.2.1. For a definition of the NASA Data Processing Levels go to: [https://science.nasa.gov/earth-science/earth-science-data/data-processing-levels-for-eosdis-data-products .](https://science.nasa.gov/earth-science/earth-science-data/data-processing-levels-for-eosdis-data-products)

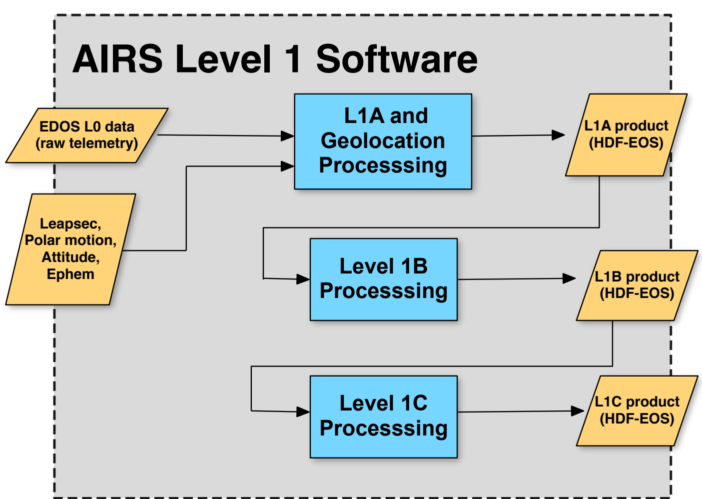


Figure 2.2.1. AIRS Level 1 processing flow

AIRS Level 1A processing extracts counts for the Earth, Space and On-Board Calibrator views from raw binary Level 0 data and converts engineering counts from telemetry of the instrument subsystems into physical measurements such as instrument temperatures and voltages. L1A geolocation processing derives spacecraft positions and attitude and projects AIRS sounding fields-of-views (FOVs) onto the Earth's surface with geolocation, view angles, solar angles, and surface parameters such as elevations and land fractions. All the geolocation parameters from L1A processing are propagated to the L1B and L1C products.

L1B processing then computes and applies calibration coefficients (gain and offset) and non-linearity and polarization corrections to the L1A Earth, Space and On-board Calibrator counts to convert them to physical radiances. Technical and scientific details of the L1B calibration can be found in the AIRS Level 1B Algorithm Theoretical Basis Document (ATBD) (Aumann 2000).

Level 1C identifies channels with anomalous values and replaces their radiances with synthesized values. Then it eliminates channels with overlapping spectral coverage and creates synthesized radiance values where there are small gaps in the spectral coverage of the AIRS instrument. Finally, it makes small adjustment to compensate for changes in the spectral sensitivity of the instrument.

Technical and scientific details of L1C can be found in the AIRS Level 1C Algorithm Theoretical Basis Document (ATBD) (Aumann 2020).

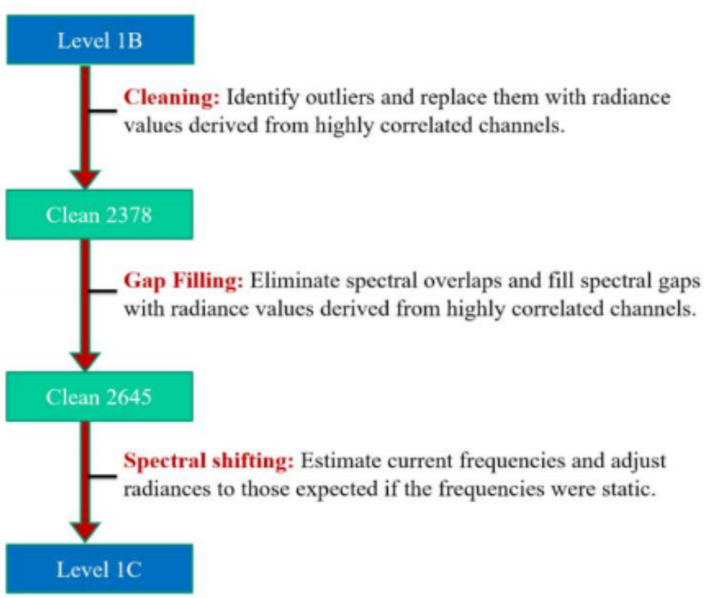


Figure 2.2.2 Processing steps in Level 1C

2.3 Data Organization

AIRS L1C products are divided into a series of six-minute segments with one segment per file. Each file contains all observations made during a period of exactly 6 minutes. For each day there are 240 files (also known as granules), identified by the granule number in the filename. For granule start time details, refer to section 2.1.

2.4 File Format and Structure

The AIRS L1C files, similar to the AIRS L1B files, are in HDF-EOS Swath format, which can also be read as HDF4 or netCDF3.

All data is in one main swath object, named “`L1C_AIRS_Science`”. Data is structured to align with AIRS observing geometry: 135 scans in the along-track “`GeoTrack`” dimension by 90 FOVs in the cross-track “`GeoXTrack`” dimension.

2.5 Metadata

AIRS L1C granules are created with internal HDF-EOS global metadata attributes and external ECS-compliant ODL format metadata files. On ingest to the GES DISC archive, the external metadata file is parsed to populate XML format metadata files for use in the archive system. The original ODL metadata is wholly encapsulated as a distinct attribute in the XML file. The XML files are stored along-side the data files in the archive, and can be accessed via HTTPS.

2.6 Missing Data / Fill Values

On occasion, there will be data that is missing for various reasons. In the situation where there are incomplete granules within the 6-minute product granule, the missing data will be filled with ‘Fill Values’. The fill value will exist in the same location the missing data would exist. This will preserve the shape of the 6-minute granule. With this in mind, it is advised to check the data for fill values before use. The fill value for all floating-point types is -9999.0.

2.7 File Naming Convention

File names for AIRS L1C products are composed of tokens separated by the delimiter '.'. They have the form:

`AIRS.yyyy.mm.dd.ggg.L1C.AIRS_Rad.vm.m.r.b.Ftttttttttt.hdf`

where:

`AIRS` is the literal string "AIRS" to identify this as an AIRS-instrument-suite product.

`yyyy.mm.dd` is the year/month/day of the start of the granule.

`ggg` is the granule number in day (001 - 240).
Note: The numbering system from 001 - 240 is closely tied to the idea of 6-minute granules triggered at precise intervals keyed to total elapsed time since start of year 1958.

`L1C.AIRS_Rad` is the processing level (L1C), instrument (AIRS), and product type (radiances).

`vm.m.r.b` is the PGE Version uniquely identifying a configuration of source code + static ancillary files. "v" is the literal character 'v'. It is followed by four numbers separated by three "."s. These are the major & minor version numbers, a release number, and a build number. Example: "v6.7.2.0" is the official (.0) build of release 2 of version 6.7.

`F` is processing facility ID:
"G" for NASA GSFC GES DISC official archival system
"A" for NASA JPL AIRS TLSCF official processing
"D" for any direct broadcast station
"X" for anything else

`tttttttttttt` is AIRS run tag (00000000000 - 99999999999).
This field is designed to ensure LocalGranuleIDs are unique, even when the same software is used to reprocess the same data. It is local processing time as yyyydoyhhmmss. (year, day-of-year (Julian day), hour, minute, second).
(Note: this corresponds to Product-Specific Attribute (PSA) "AIRSRunTag").

`hdf` is the filetype extension for all HDF products (including HDF-EOS)

Here's a sample AIRS L1C file name:

`AIRS.2019.01.01.235.L1C.AIRS_Rad.v6.7.2.0.G19354103153.hdf`

2.8 Time Representation

Times in the AIRS L1C product are generally represented as TAI93. However, granule start and end times are provided in both UTC and TAI93 representations as a convenience to users.

International Atomic Time (TAI) is expressed as number of seconds elapsed on the surface of the Earth since some reference UTC time. The term "TAI93" indicates that the reference time is the beginning of the year 1993, or 1993-01-01T00:00:00Z. This reference time was chosen to be consistent with data products from other instruments, and to allow for precise representation of times spanning the expected mission length. The "Time" geolocation field contains TAI93 values for each spectrum.

Coordinated Universal Time (UTC) is the international standard for representation of time. UTC times are expressed in human-readable form, as a set of values indicating year, month, day, hour and so on.

Timestamps in AIRS L1C product attributes are represented as UTC and formatted according to the "ISO 8601:2004" standard. For example, the time January 25, 2016 at 13:00 may be represented as either of the following:

2016-01-25T13:00Z
20160125T1300

The character "Z" indicates "Zulu time", or UTC.

The longer form is used in metadata attribute PRODUCTIONDATETIME. A variant of this with the date and time fields separated is used in metadata attributes

EQUATORCROSSINGDATE/EQUATORCROSSINGTIME,
RANGEBEGINNINGDATE/RANGEBEGINNINGTIME, and
RANGEENDIDINGDATE/RANGEENDINGTIME.

In the global attributes inside the file, the granule start time is expressed as an equivalent in a series of attributes: "start_year", "start_month", … "start_sec", as well as in units of TAI93 in the attribute "start_Time".

Leap seconds are one-second adjustments that are occasionally applied to UTC as 23:59:60, to account for irregularities in the rotation of the Earth. There were 27 leap seconds applied to UTC between Jan 1, 1958 and Jan 1, 1993. Between Jan 1, 1993 and Jan 1, 2017, an additional 10 leap seconds were applied to UTC. Leap seconds must be accounted for when doing certain kinds of time calculations, especially in astronomy and satellite applications. Leap seconds can occur on December 31 or June 30 of a given year, and are announced months in advance.

Leap seconds must be accounted for in the following operations:

- When calculating exact elapsed time between two UTC times. If one or more leap seconds were inserted between the UTC endpoints, they must be accounted for in order for the result to be accurate.

- When converting between UTC and TAI times. Any leap seconds that occurred between the TAI reference time and the UTC time must be accounted for, or the result will be wrong.

- When comparing TAI times with different reference times, or converting from one TAI reference time to the other. Any leap seconds that occurred between the reference times must be accounted for, or the result will be wrong.

In general, these operations can be error-prone. Therefore, it is recommended that time calculations and conversions be done with leap-second-aware third-party tools that rely on an up-to-date table of leap seconds, such as the "astropy" python package.

2.9 Channel wavenumbers

The Level 1C product eliminates spectral overlaps in the Level 1B product and adds synthesized channels in the gaps between instrument modules. As a result, the spectral "Channel" dimension in L1C is 2645 instead of 2378, as in L1B. For both the L1B and L1C, the wavenumber sets are present in each file in a data field named "`nominal_freq`".

Note that there are small differences in `nominal_freq` even for channels which are not synthesized. This is because the L1B set assumes a nominal -13.5 micron focal plane shift, while the L1C set is defined to match the state of the instrument in January 2010 (~-13.8 micron focal plane shift) and also incorporates some small refinements to the positions of detectors on the focal plane.

The 2645-channel set in L1C provides continuous spectral coverage from 649.6 to 2665 cm^{-1}, with one gap from 1614-2181 cm^{-1}. See the AIRS L1C ATBD [Aumann 2020] for details of this process.

Channel wavenumbers and spectral response functions (SRFs) can be found at [Strow 2020].

L1C data fields `ChanID` and `ChanMapL1b` provide the information needed to map back and forth between the L1B and L1C channel sets. Note that these fields are present in every L1C product granule but do not change.

If you have a specific L1C channel and you want to find out whether it is synthesized in L1C to fill a gap in L1B spectral coverage, use `ChanID`. If the value of `ChanID` is greater than

2378 then this is a synthesized gap channel. Otherwise, the value of ChanID will be in [1, 2378] and it is the index of the corresponding channel in the L1B products.

If you have a specific L1B channel and you want to find out if it is preserved in L1C or eliminated to remove an overlap, use ChanMapL1b. If the value of ChanMapL1b is -1 then this channel is not present in the L1C file. Otherwise, the value is in [1, 2645] and it is the index of the channel in the L1C 2645-channel set.

3.0 Data Content

The AIRS Level 1C data products are written in HDF-EOS swath format and use the swath object structure, dimensions, geolocation and science data fields, and global attributes.

Attention should be given to quality flags (section 3.5) and checked for fill values (section 2.6) before being used for any analysis or higher processing of the L1C product.

Selected fields are highlighted in this section. A full profile of the contents of the files is included in the tables of Appendix B.

3.1 Dimensions

Dimension objects are a fundamental part of the HDF and HDF-EOS product profiles. They name and define the sizes of the data arrays.

The key horizontal dimensions for L1C are GeoXTrack (=90) and GeoTrack (=135). These are the cross-track and along-track dimensions respectively. Over the six minutes of observations captured in each file, the instrument sweeps left-to-right 135 times, each time capturing 90 spectra.

The Channel (=2645) dimension is the spectral dimension. Channels are listed in order of increasing wavenumber. The nominal_freq field gives the wavenumbers for each channel.

3.2 Global Attributes

Global attributes, sometimes referred to as 'file-level attributes', provide information about the entire file or 6-minute granule. This includes observation times, data provenance, geolocation information, etc. Many attributes are required to conform to the EOSDIS standard.

https://wiki.earthdata.nasa.gov/display/NASAISO/EOSDIS+Core+System+%28ECS%29+Metadata+Home

A full definition of the global attributes can be found in the "Attributes" table of Appendix B.

3.3 Science Variables

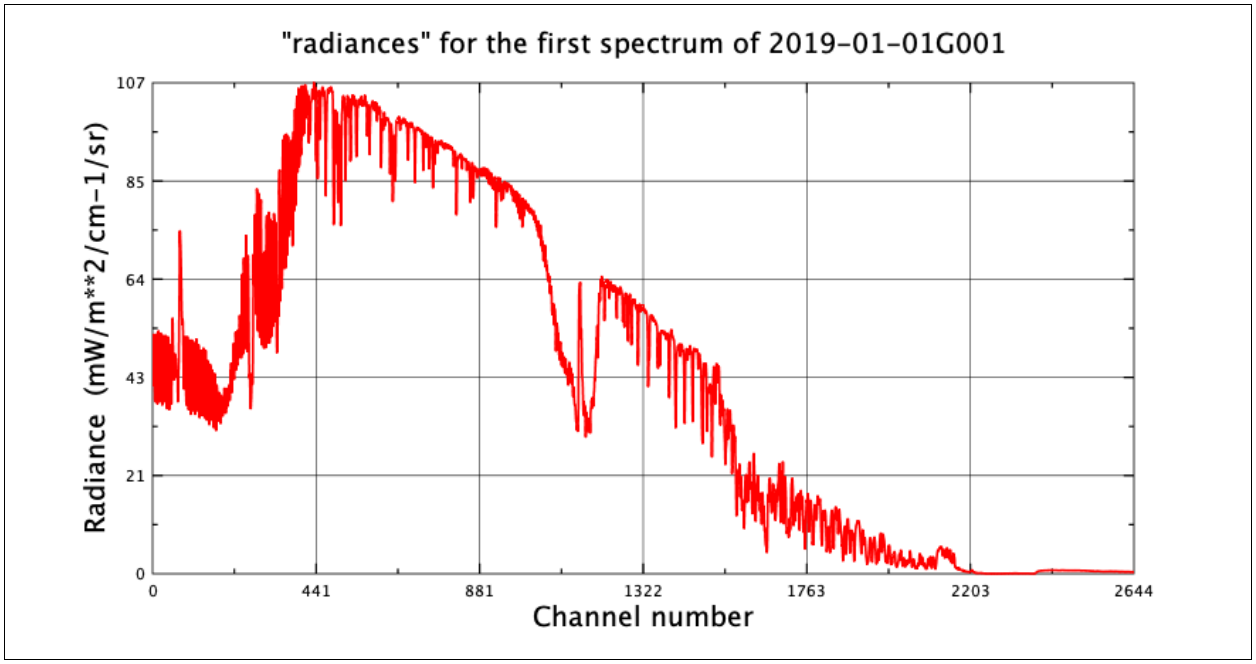
Science data fields are the main content of the HDF-EOS swath file. These fields are expected to be the most heavily used. Included in this group are radiances, quality control, satellite and solar geometry information, surface information, and related metadata.

`radiances` - the `radiances` field contains observed or synthesized radiance values for all 2645 wavenumbers for every observation, adjusted to a constant wavenumber set. Radiances are provided in units of mW/m^2/cm^{-1}/sr but are frequently used in units of brightness temperature after conversion using the Planck equation.

`nominal_freq` - the wavenumbers (cm^{-1}) for each of the 2645 channels is provided in this field.

See section 3.4 below for information on the location of each observation and static characterization of the surface, angle of observation, and solar illumination.

See section 3.5 below for information on quality characterization.



3.4 Geolocation

As part of the HDF-EOS swath structure, the fundamental geolocation fields are treated specially. These are `Latitude`, `Longitude`, and `Time`, and they give the location and time of associated with each spectrum. The location of each spectrum is the boresight location at the center of the beam. Each spectrum actually reports the mean radiances over an area (Field-of-view or FOV) surrounding this point. Near nadir the area is approximately a circle with a diameter of 14 km. Towards the edges of the granule the area covered expands to an ellipse approximately 20 x 30 km.

`landFrac` - another useful field is land fraction. This gives the fraction of the area of the FOV which is land. Depending on application, users may want to treat any FOV with `landFrac` under 0.01 as "sea" or may include only cases where `landFrac` is exactly zero.

`satzen` – the satellite zenith angle field gives the angle in degrees between the vertical and the vector from the FOV to the instrument. It provides information on how much atmosphere is between the surface and the instrument.

`solzen` – the solar zenith angle field gives the angle between the vertical and the sun. 90 degrees can be used as the threshold between day and night.

3.5 Quality Control

Because the L1C repairs most issues, most `radiances` data will be useable for many purposes. There is a per-spectrum flag named state which will be nonzero when downlinked data was lost or the instrument was not collecting science data. Only use data with `state` equal to zero.

For direct retrievals using a limited number of channels, users may wish to avoid specific channels which are synthesized, marked by a nonzero value of `L1cSynthReason`.

The `NeN` variable gives a noise level in radiance units (mW/m^2/cm^{-1}/sr) for each value, so it can be used to weight channels when combining them or can be used with a threshold to avoid noisy channels. A flag value of `999.0` is assigned to all synthesized `radiances`.

Applications which use individual spectra may also wish to avoid using cases where scene inhomogeneity has had a strong impact, but applications which average many spectra together can ignore this. See Section 3.6 for details. To avoid inhomogeneous scenes, avoid any spectrum where the total number of synthesized values exceeds ~200, or screen out cases with |`Inhomo850`| > ~0.84.

3.6 Known issues

AIRS Level 1C includes data that are synthesized using a PC reconstruction and other methods. Channels containing synthesized data are flagged in the `L1cProc` and `L1cSynthReason` fields. Their use in science investigations and other applications should be limited to cases where use of synthesized data is appropriate. [Aumann 2020, section 2.4.1 and Appendix C]

Imperfect co-registration between the AIRS channels distorts L1B spectra for highly inhomogeneous scenes. L1C mitigates the effect, but does not eliminate it. [Pagano 2015]

Some known artifacts in the AIRS v5 L1B are not repaired in this version of L1C, including [Manning 2017]:

- Up to 5 K warming trend near 2600 cm^{-1} for very cold scenes.
- Bias differences of up to 0.5 K around 860 cm^{-1} between some channels' redundant A and B detectors.
- Trend of up to 0.3 K for very cold scenes near 1100 cm^{-1}.

4.0 Options for Reading the Data

The AIRS L1C files are written in HDF-EOS swath format. Because HDF-EOS builds upon the HDF4 data model using netCDF3 as the storage layer, a user of the data product can take full advantage of tools and libraries readily available to access the data.

Tools and examples to access HDF-EOS from a variety of languages can be found at:
https://hdfeos.org/examples/index.php

One good tool to visualize HDF-EOS files such as AIRS L1C is Panoply:
https://www.giss.nasa.gov/tools/panoply/download/

See the sample images in Appendix A made with Panoply.

5.0 Data Services

AIRS Level 1C products are available to the user community via the Goddard Distributed Active Archive Center (GDAAC) also referred to as the Goddard Earth Sciences Data and Information Services Center (GES DISC). See Section 1.5 "Where to find the Product" of this document. There you will find additional information and documentation about this product and other products of interest, as well as ordering and data sub-setting tools and services:
https://disc.gsfc.nasa.gov
Use the ECS shortname AIRICRAD in the search string to quickly find the AIRS Level 1C product.

This link will take you directly to the Level 1C products:
https://disc.gsfc.nasa.gov/datasets?keywords=AIRICRAD&page=1

The Level 1C data can also be accessed via doi: 10.5067/VWD3DRC07UEN

In addition to the data files, there you can also get daily granule maps, showing the location of each granule for each day at
https://disc.gsfc.nasa.gov/datasets/AIRXAMAP_005/summary

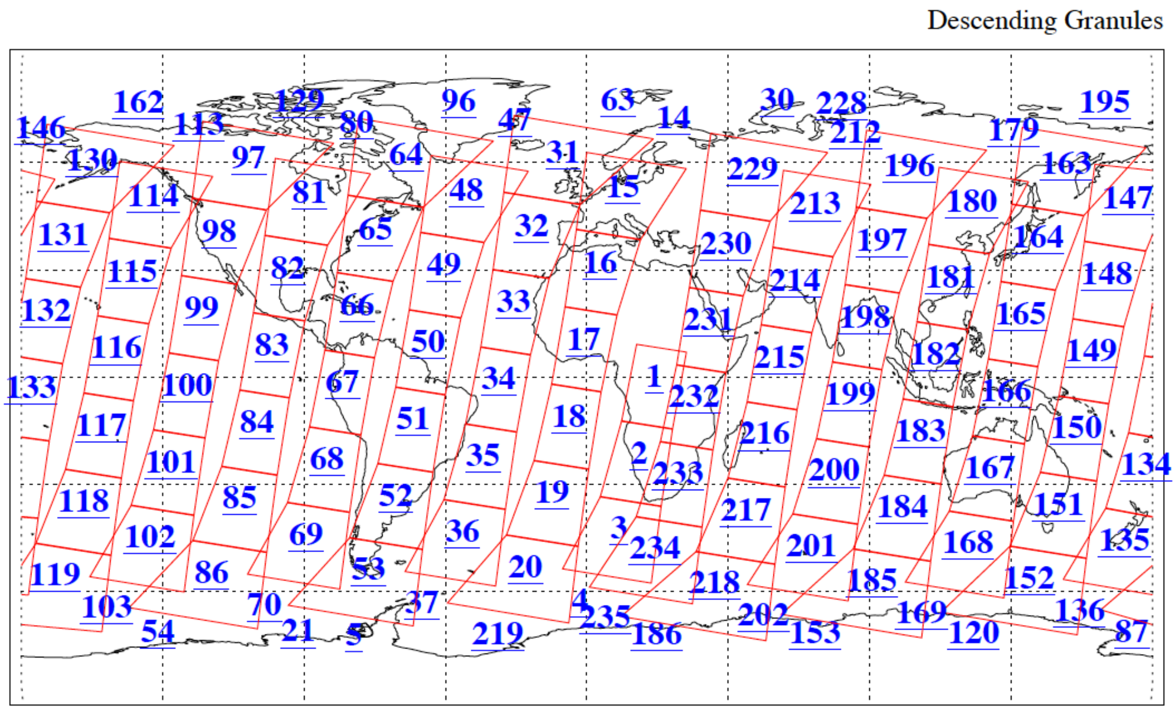


Figure 5.1. Granule map for nighttime data 2019-01-01. Granule 1 is used in Appendix A.

Data at the GDAAC is organized by unique shortnames and version numbers.

shortname_version	Description
AIRS Level 1C products described in this document	
AIRICRAD_6.7	AIRS L1C
Related data sets at GDAAC	
AIRXAMAP_005	AIRS granule maps
AIRIBRAD_005	AIRS L1B used as input to L1C

6.0 Acronyms and Abbreviations

AIRS	Atmospheric InfraRed Sounder
ATBD	Algorithm Theoretical Basis Document
ECS	EOSDIS Core System
EDOS	EOS Data and Operations System
EOS	Earth Observing System
EOSDIS	Earth Observing System Data and Information System
ESDIS	Earth Science Data and Information System
FOV	Field Of View
GES DISC	Goddard Earth Science Data and Information Services Center
JPL	Jet Propulsion Laboratory
NASA	National Aeronautics and Space Administration
SRF	Spectral Response Function
TAI	International Atomic Time
UTC	Coordinated Universal Time

7.0 References

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Radiometric Stability Validation of 17 Years of AIRS Data Using Sea Surface Temperatures. *Geophysical Research Letters*, 46, 12504–12510. https://doi.org/10.1029/2019GL085098

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https://docserver.gesdisc.eosdis.nasa.gov/public/project/AIRS/AIRICRAD.v6.7.ATBD.pdf

Manning, E. M. & Aumann, H. H. (2017).
Hyperspectral sounder performance for cold scenes. Proc. SPIE 10402, Earth Observing Systems XXII, 1040225 (5 September 2017); https://doi.org/10.1117/12.2273398

Pagano, T. S., Aumann, H. H., Hagan, D. E., & Overoye, K. (2003).
Prelaunch and in-flight radiometric calibration of the Atmospheric Infrared Sounder (AIRS). *IEEE Transactions on Geoscience and Remote Sensing*, 41, no. 2, 265–273, Feb 2003. https://doi.org/10.1109/TGRS.2002.808324

Pagano, T. S., Aumann, H. H., Manning, E. M., Elliott, D. A., & Broberg, S. E. (2015).
Improving AIRS radiance spectra in high contrast scenes using MODIS. Proc. SPIE 9607, Earth Observing Systems XX, 96070K (8 September 2015).
https://doi.org/10.1117/12.2188311

Pagano, T. S., Aumann, H. H., Broberg, S., Manning, E., Overoye, K., & Weiler, M. (2018).
Updates to the absolute radiometric accuracy of the AIRS on Aqua. Proc. SPIE 10781, Earth Observing Missions and Sensors: Development, Implementation, and Characterization V, 107810P (23 October 2018); https://doi.org/10.1117/12.2324605

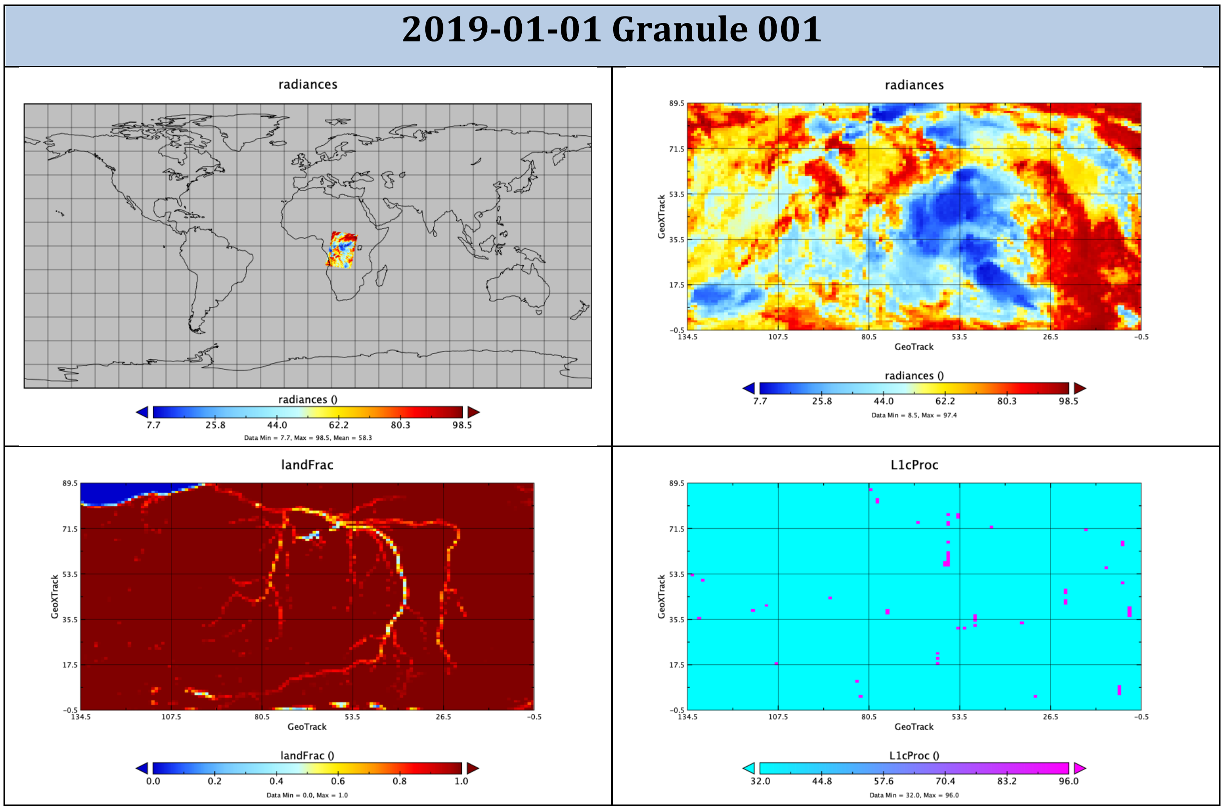
Strow, L. L., Hannon, S. E., Weiler, M., Overoye, K., Gaiser, S. L., & Aumann, H. H. (2003).
Prelaunch spectral calibration of the atmospheric infrared sounder (AIRS). *IEEE Transactions on Geoscience and Remote Sensing*, 41, no. 2, 274–286.
https://doi.org/10.1109/TGRS.2002.808245

Strow, L. L. (2020). AIRS Spectral Response Functions, UMBC Atmospheric Spectroscopy Lab. Retrieved from https://asl.umbc.edu/reports/srfs/

Appendix A: Sample Images

These images for Granule #1 of 2019-01-01 were generated with Panoply from file:

`AIRS.2019.01.01.001.L1C.AIRS_Rad.v6.7.2.0.G19354093716.hdf`



The first image shows `radiances` (mW/m^2/cm^{-1}/sr) for channel #859 (922.7 cm^{-1}) of this granule on a global map.

The second image shows the same field plotted as a 135 x 90 array of points. Cold regions are cloud.

The 3rd image is the land faction. We can see a little ocean in the corner and a river system.

The last image shows the `L1cProc` field, telling what processing was applied for this channel at each point. Most are 32, which means only spectral corrections were applied. The magenta points show where synthesized values were substituted because of a problem in the L1B data.

Appendix B: AIRS Level 1C HDF-EOS File Definition

Interface Specification Version 6.7.2.0

2019-11-26
ESDT ShortName = "AIRICRAD"
DOI = “10.5067/VWD3DRC07UEN”
Swath Name = "L1C_AIRS_Science"
Level = "level1C"
# Footprints = 90
# scanlines per scanset = 3

Dimensions

These fields define all dimensions that can be used for HDF-EOS swath fields.

The names "GeoTrack" and "GeoXTrack" have a special meaning for this document: "Cross-Track" data fields have a hidden dimension of "GeoXTrack"; "Along-Track" data fields have a hidden dimension of "GeoTrack"; Full Swath Data Fields have hidden dimensions of both "GeoTrack" and "GeoXTrack".

Name	Value	Explanation
GeoXTrack	90	Dimension across track for footprint positions. Same as number of footprints per scanline. -- starting at the left and increasing towards the right as you look along the satellite's path
GeoTrack	135	Dimension along track for footprint positions. Same as number of scanlines in granule. Parallel to the satellite's path, increasing with time. (Nominally 45 for Level-2, AMSU-A, and AIRS/Vis low-rate engineering; 135 for AIRS/Vis and HSB high-rate quantities)
Channel	2645	Dimension of channel array. (This list of channels removes the overlaps and fills the gaps found in the 2378-channel set from the AIRS instrument.)
L1bChannel	2378	Dimension of channel array used in L1B. (In this list channels are generally in order of increasing wavenumber, but because frequencies can vary and because all detectors from a physical array of detector elements (a "module") are always grouped together there are sometimes small reversals in wavenumber order where modules overlap.)
Module	17	Number of modules on the focal plane in which airs channels are grouped. The order is M-01a, M-02a, M-01b, M-02b, M-04d, M-04c, M-03, M-04b, M-04a, M-05, M-06, M-07, M-08, M-09, M-10, M-11, M-12.

Geolocation Fields

These fields appear for every footprint (GeoTrack * GeoXTrack times) and correspond to footprint center coordinates and "shutter" time.

Name	Explanation
Latitude	Footprint boresight geodetic Latitude in degrees North (-90.0 ... 90.0)
Longitude	Footprint boresight geodetic Longitude in degrees East (-180.0 ... 180.0)
Time	Footprint "shutter" TAI Time: floating-point elapsed seconds since Jan 1, 1993

Attributes

These fields appear only once per granule and use the HDF-EOS "Attribute" interface

Name	Type	Explanation
processing_level	string of 8-bit characters	Zero-terminated character string denoting processing level ("level1C")
instrument	string of 8-bit characters	Zero-terminated character string denoting instrument ("AIRS")
DayNightFlag	string of 8-bit characters	Zero-terminated character string set to "Night" when the subsatellite points at the beginning and end of a granule are both experiencing night according to the "civil twilight" standard (center of refracted sun is below the horizon). It is set to "Day" when both are experiencing day, and "Both" when one is experiencing day and the other night. "NA" is used when a determination cannot be made.
AutomaticQAFlag	string of 8-bit characters	Zero-terminated character string denoting granule data quality: (Always "Passed", "Failed", or "Suspect")
NumTotalData	32-bit integer	Total number of expected scene footprints
NumProcessData	32-bit integer	Number of scene footprints which are present and can be processed routinely (state = 0)
NumSpecialData	32-bit integer	Number of scene footprints which are present and can be processed only as a special test (state = 1)
NumBadData	32-bit integer	Number of scene footprints which are present but cannot be processed (state = 2)
NumMissingData	32-bit integer	Number of expected scene footprints which are not present (state = 3)
NumLandSurface	32-bit integer	Number of scene footprints for which the surface is more than 90% land
NumOceanSurface	32-bit integer	Number of scene footprints for which the surface is less than 10% land
node_type	string of 8-bit characters	Zero-terminated character string denoting whether granule is ascending, descending, or pole-crossing: ("Ascending" and "Descending" for entirely ascending or entirely descending granules, or "NorthPole" or "SouthPole" for pole-crossing granules. "NA" when determination cannot be made.)

start_year	32-bit integer	Year in which granule started, UTC (e.g. 1999)
start_month	32-bit integer	Month in which granule started, UTC (1 ... 12)
start_day	32-bit integer	Day of month in which granule started, UTC (1 ... 31)
start_hour	32-bit integer	Hour of day in which granule started, UTC (0 ... 23)
start_minute	32-bit integer	Minute of hour in which granule started, UTC (0 ... 59)
start_sec	32-bit floating-point	Second of minute in which granule started, UTC (0.0 ... 59.0)
start_orbit	32-bit integer	Orbit number of mission in which granule started
end_orbit	32-bit integer	Orbit number of mission in which granule ended
orbit_path	32-bit integer	Orbit path of start orbit (1 ... 233 as defined by EOS project)
start_orbit_row	32-bit integer	Orbit row at start of granule (1 ... 248 as defined by EOS project)
end_orbit_row	32-bit integer	Orbit row at end of granule (1 ... 248 as defined by EOS project)
granule_number	32-bit integer	Number of granule within day (1 ... 240)
num_scansets	32-bit integer	Number of scansets in granule (1 ... 45)
num_scanlines	32-bit integer	Number of scanlines in granule (3 * num_scansets)
start_Latitude	64-bit floating-point	Geodetic Latitude of spacecraft at start of granule (subsatellite location at midpoint of first scan) in degrees North (-90.0 ... 90.0)
start_Longitude	64-bit floating-point	Geodetic Longitude of spacecraft at start of granule (subsatellite location at midpoint of first scan) in degrees East (-180.0 ... 180.0)
start_Time	64-bit floating-point	TAI Time at start of granule (floating-point elapsed seconds since start of 1993)
end_Latitude	64-bit floating-point	Geodetic Latitude of spacecraft at end of granule (subsatellite location at midpoint of last scan) in degrees North (-90.0 ... 90.0)
end_Longitude	64-bit floating-point	Geodetic Longitude of spacecraft at end of granule (subsatellite location at midpoint of last scan) in degrees East (-180.0 ... 180.0)
end_Time	64-bit floating-point	TAI Time at end of granule (floating-point elapsed seconds since start of 1993)
eq_x_longitude	32-bit floating-point	Longitude of spacecraft at southward equator crossing nearest granule start in degrees East (-180.0 ... 180.0)
eq_x_tai	64-bit floating-point	Time of eq_x_longitude in TAI units (floating-point elapsed seconds since start of 1993)
LonGranuleCen	16-bit integer	Geodetic Longitude of the center of the granule in degrees East (-180 ... 180)
LatGranuleCen	16-bit integer	Geodetic Latitude of the center of the granule in degrees North (-90 ... 90)
LocTimeGranuleCen	16-bit integer	Local solar time at the center of the granule in minutes past midnight (0 ... 1439)
num_fpe	16-bit integer	Number of floating point errors
orbitgeoqa	32-bit unsigned integer	See Appendix D of the AIRS Processing Files Description
num_satgeoqa	16-bit integer	Number of scans with problems in satgeoqa

num_glintgeoqa	16-bit integer	Number of scans with problems in glintgeoqa
num_moongeoqa	16-bit integer	Number of scans with problems in moongeoqa
num_ftptgeoqa	16-bit integer	Number of footprints with problems in ftptgeoqa
num_zengeoqa	16-bit integer	Number of footprints with problems in zengeoqa
num_demgeoqa	16-bit integer	Number of footprints with problems in demgeoqa
Rdiff_swindow_M1a_chan	16-bit integer	Array M1a channel used as one reference in calculating Rdiff_swindow. (index into radiance & wavenumber arrays 1...2378)
Rdiff_swindow_M2a_chan	16-bit integer	Array M2a channel used as one reference in calculating Rdiff_swindow. (index into radiance & wavenumber arrays 1...2378)
Rdiff_lwindow_M8_chan	16-bit integer	Array M8 channel used as one reference in calculating Rdiff_lwindow. (index into radiance & wavenumber arrays 1...2378)
Rdiff_lwindow_M9_chan	16-bit integer	Array M9 channel used as one reference in calculating Rdiff_lwindow. (index into radiance & wavenumber arrays 1...2378)
CF_Version	string of 8-bit characters	Cloud Filter Version Identification. Identifies the set of thresholds used in determination of spectral_clear_indicator.
NumSaturatedFOVs	16-bit unsigned integer	Number of scene fields-of-view (out of a nominal 1350) in which the downlinked counts overflowed.
NumUnderflowFOVs	16-bit unsigned integer	Number of scene fields-of-view (out of a nominal 1350) in which the downlinked counts underflowed.
NumCalFOVsOutOfBounds	16-bit unsigned integer	Number of calibration fields-of-view (out of a nominal 810) in which the downlinked counts underflowed or overflowed.
NumSO2FOVs	16-bit unsigned integer	Number of fields-of-view (out of a nominal 1350) with a signifcant SO_2 concentration based on the value of BT_diff_SO_2.
granules_present	string of 8-bit characters	Zero-terminated character string denoting which adjacent granules were available for smoothing ("All" for both previous & next, "Prev" for previous but not next, "Next" for next but not previous, "None" for neither previous nor next)

Per-Granule Data Fields

These fields appear only once per granule and use the HDF-EOS "Field" interface.

Name	Type	Extra Dimensions	Explanation
nominal_freq	32-bit floating-point	Channel (= 2645)	Nominal frequencies (cm**-1) of each channel
ChanID	16-bit unsigned integer	Channel (= 2645)	A unique identifier for each channel. For those channels which are present in Level 1B this identifier is identical to the 1-based index of the channel in Level 1B. For channels which are added in Level 1C to fill gaps in the Level 1B record, this is a unique identifier with value > 2378. Note: ChanID are not sequential.
ChanMapL1b	16-bit integer	L1bChannel (= 2378)	A map from the 2378-channel Level 1B channel set into the 2645-channel Level 1C set. For Level 1B channels which are used in Level 1C, this will be a number in [1,2645] giving the 1-based index in the Level 1C list for this channel. For overlap Level 1B channels which are not used in Level 1C, this will be -1.
L1cNumSynth	32-bit unsigned integer	Channel (= 2645)	A count of how many spectra in the granule have synthesized values for each channel. Fill channels will always have value 12150 (=90*135)

Along-Track Data Fields

These fields appear once per scanline (GeoTrack times).

Name	Type	Extra Dimensions	Explanation
satheight	32-bit floating-point	None	Satellite altitude at nadirTAI in km above reference ellipsoid (e.g. 725.2)
satroll	32-bit floating-point	None	Satellite attitude roll angle at nadirTAI (-180.0 ... 180.0 angle about the +x (roll) ORB axis, +x axis is positively oriented in the direction of orbital flight completing an orthogonal triad with y and z.)
satpitch	32-bit floating-point	None	Satellite attitude pitch angle at nadirTAI (-180.0 ... 180.0 angle about +y (pitch) ORB axis. +y axis is oriented normal to the orbit plane with the positive sense opposite to that of the orbit's angular momentum vector H.)
satyaw	32-bit floating-point	None	Satellite attitude yaw angle at nadirTAI (-180.0 ... 180.0 angle about +z (yaw) axis. +z axis is positively oriented Earthward parallel to the satellite radius vector R from the spacecraft

			center of mass to the center of the Earth.)
glintlat	32-bit floating-point	None	Solar glint geodetic latitude in degrees North at nadirTAI (-90.0 ... 90.0)
glintlon	32-bit floating-point	None	Solar glint geodetic longitude in degrees East at nadirTAI (-180.0 ... 180.0)
nadirTAI	64-bit floating-point	None	TAI time at which instrument is nominally looking directly down. (between footprints 15 & 16 for AMSU or between footprints 45 & 46 for AIRS/Vis & HSB) (floating-point elapsed seconds since start of 1993)
sat_lat	64-bit floating-point	None	Satellite geodetic latitude in degrees North (-90.0 ... 90.0)
sat_lon	64-bit floating-point	None	Satellite geodetic longitude in degrees East (-180.0 ... 180.0)
scan_node_type	8-bit integer	None	'A' for ascending, 'D' for descending, 'E' when an error is encountered in trying to determine a value.
satgeoqa	32-bit unsigned integer	None	See Appendix D of the AIRS Processing Files Description
glintgeoqa	16-bit unsigned integer	None	See Appendix D of the AIRS Processing Files Description
moongeoqa	16-bit unsigned integer	None	See Appendix D of the AIRS Processing Files Description
orbit_phase_deg	32-bit floating-point	None	Orbit phase in degrees. 0.0 is nighttime equator crossing. 90.0 is near the south pole. 180.0 is near the daytime equator crossing. 270.0 is near the north pole. [0.0, 360.0]
shift_y0	32-bit floating-point	Module (= 17)	Focal plane shift in the y (spectral dispersion) direction relative to prelaunch nominal. (microns)

Full Swath Data Fields

These fields appear for every footprint of every scanline in the granule (GeoTrack * GeoXTrack times).

Name	Type	Extra Dimensions	Explanation
radiances	32-bit floating-point	Channel (= 2645)	Radiances for each channel in $mW/m^2/cm^{-1}/sr$
scanang	32-bit floating-point	None	Scanning angle of AIRS instrument with respect to the AIRS Instrument for this footprint (-180.0 ... 180.0, negative at start of scan, 0 at nadir)
satzen	32-bit floating-point	None	Spacecraft zenith angle (0.0 ... 180.0) degrees from zenith (measured relative to the geodetic vertical on the reference (WGS84) spheroid and including corrections outlined in EOS SDP toolkit for normal accuracy.)
satazi	32-bit floating-point	None	Spacecraft azimuth angle (-180.0 ... 180.0) degrees E of N GEO)
solzen	32-bit floating-point	None	Solar zenith angle (0.0 ... 180.0) degrees from zenith (measured relative to the geodetic vertical on the reference (WGS84) spheroid and including corrections outlined in EOS SDP toolkit for normal accuracy.)
solazi	32-bit floating-point	None	Solar azimuth angle (-180.0 ... 180.0) degrees E of N GEO)
sun_glint_distance	16-bit integer	None	Distance (km) from footprint center to location of the sun glint (-9999 for unknown, 30000 for no glint visible because spacecraft is in Earth's shadow)
topog	32-bit floating-point	None	Mean topography in meters above reference ellipsoid
topog_err	32-bit floating-point	None	Error estimate for topog
landFrac	32-bit floating-point	None	Fraction of spot that is land (0.0 ... 1.0)
landFrac_err	32-bit floating-point	None	Error estimate for landFrac

ftptgeoqa	32-bit unsigned integer	None	See Appendix D of the AIRS Processing Files Description
zengeoqa	16-bit unsigned integer	None	See Appendix D of the AIRS Processing Files Description
demgeoqa	16-bit unsigned integer	None	See Appendix D of the AIRS Processing Files Description
state	32-bit integer	None	Data state: 0:Process, 1:Special, 2:Erroneous, 3:Missing
Rdiff_swindow	32-bit floating-point	None	Radiance difference in the 2560 cm**-1 window region used to warn of possible errors caused by scene non-uniformity and misalignment of the beams: radiance(Rdiff_swindow_M1a_chan) - radiance(Rdiff_swindow_M2a_chan). (radiance units)
Rdiff_lwindow	32-bit floating-point	None	Radiance difference in the longwave window(850 cm**-1) used to warn of possible errors caused by scene non-uniformity and misalignment of the beams: radiance(Rdiff_lwindow_M8_chan) - radiance(Rdiff_lwindow_M9_chan). (radiance units)
SceneInhomogeneous	8-bit unsigned integer	None	Threshold test for scene inhomogeneity, using band-overlap detectors (bit fields).; Bit 7 (MSB, value 128): scene is inhomogeneous, as determined by the Rdiff_swindow threshold. For v5.0 the test is abs(Rdiff_swindow) > 5 * sqrt(NeN(Rdiff_swindow_M1a_chan)^2 + NeN(Rdiff_swindow_M2a_chan)); Bit 6 (value 64): scene is inhomogeneous, as determined by the Rdiff_lwindow threshold. For v5.0 the test is abs(Rdiff_lwindow) > 5 * sqrt(NeN(Rdiff_lwindow_M8_chan)^2 + NeN(Rdiff_lwindow_M9_chan)); Bits 5-0: unused (reserved)
dust_flag	16-bit integer	None	Experimental flag telling whether dust was detected in this scene; 1: Dust detected; 0: Dust not detected; -1: Dust test not valid because of land; -2: Dust test not valid because of high latitude; -3: Dust test not valid because of suspected cloud; -4: Dust test not valid because of bad input data
dust_score	16-bit integer	None	Experimental dust score. Each bit results from a different test comparing radiances. Higher scores indicate more certainty of dust present. Dust probable when score is over 380. Not valid when dust_flag is negative.
spectral_clear_indicator	16-bit integer	None	Flag telling whether scene was flagged as clear by a spectral filter. Only ocean filter is validated; 2: Ocean test applied and scene identified as clear;

			1: Ocean test applied and scene not identified as clear; 0: Calculation could not be completed. Possibly some inputs were missing or FOV is on coast or on the edge of a scan or granule; -1: Unvalidated land test applied and scene not identified as clear; -2: Unvalidated land test applied and scene identified as clear
BT_diff_SO2	32-bit floating-point	None	Brightness temperature difference BT(1361.44 cm^{-1}) - BT(1433.06 cm^{-1}) used as an experimental indicator of SO_2 release from volcanoes. Values under -6 K have likely volcanic SO_2. (Kelvins)
Doppler_shift_ppm	32-bit floating-point	None	The amount by which this spectrum was shifted to remove the Doppler effect (parts per million).
AB_Weight	8-bit integer	Channel (= 2645)	A/B detector weights; -1: Channel radiance is an approximate synthesized value; 0: A weight = B weight; 1: A side only; 2: B side only
L1cProc	8-bit unsigned integer	Channel (= 2645)	Bit field, by channel, for the current spectrum. Zero means the channel was unchanged in Level 1C.; Bit 7 (MSB, value 128): This is a synthesized fill channel where the AIRS instrument does not have a detector; Bit 6: (value 64) Synthesized. See L1cSynthReason for the cause; Bit 5: (value 32) Shifted frequency; Bit 4: (value 16) radiometric correction applied (not used in release 6.0); Bit 3: (value 8) unused/reserved (value 0); Bit 2: (value 4) unused/reserved (value 0); Bit 1: (value 2) unused/reserved (value 0); Bit 0: (LSB, value 1) Output value is a dummy/filler value because data is missing or otherwise could not be processed.
L1cSynthReason	8-bit unsigned integer	Channel (= 2645)	0: value is preserved from Level 1B; 1: Synthesized because this channel falls in a gap between AIRS instrument modules; 2: Synthesized because this channel is known to be of low quality; 3: Synthesized because of bad (-9999.0) Level 1B radiance value; 4: Synthesized because of high Level 1B NeN noise measurement; 5: Synthesized because Level 1B reported a zero or negative value in the NeN noise measurement indicating that the channel is in too poor a state for noise level to be measured effectively; 6: Synthesized because the telemetry, gain, offset, or pop flag bits were set in Level 1B CalFlag (not used); 7: Synthesized because Level 1B radiance is unphysically hot; 8: Synthesized because Level 1B radiance is unphysically cold;

			9: Synthesized because Level 1B radiance is hotter than expected based on the radiances of correlated channels; 10: Synthesized because Level 1B radiance is colder than expected based on the radiances of correlated channels; 11: Synthesized because Level 1B radiance is significantly increased by scene spatial inhomogeneity; 12: Synthesized because Level 1B radiance is significantly decreased by scene spatial inhomogeneity; 100: Synthesized by runtime user command (Test mode only)
NeN	32-bit floating-point	Channel (= 2645)	Noise-equivalent Radiance (radiance units) for an assumed 250 K scene. Channels which have synthesized radiances will have a flag value of 999.0.
Inhomo850	32-bit floating-point	None	Brightness temperature difference for the adjacent edges of the M-08 and M-09 detector modules. (near 850 cm^{-1}) This is a double difference using a PC reconstructed spectrum. Absolute values over ~0.84 K indicate likely impact from spatial scene inhomogeneity (K)