Overview of the AIRS Mission: Instruments, Processing Algorithms, Products, and Documentation

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1 Introduction and Executive Summary

The Atmospheric Infrared Sounder (AIRS) instrument is a hyperspectral infrared spectrometer orbiting on the NASA Aqua spacecraft since May 2002. The primary goal of the AIRS mission is detailed, global observations of the vertical structure of the Earth's atmosphere. Its record of observations currently extends from September 2002 though the current date of mid 2020. The AIRS instrument, in conjunction with two microwave instruments, observes radiance emitted by the underlying Earth and its atmosphere, with observations covering most the Earth twice daily. AIRS spectra are resolved into over 2,000 channels, and as of this writing the AIRS instrument has obtained about 18 billion spectra. The observed radiances are used in a retrieval algorithm to infer atmospheric structure and other geophysical quantities (Chahine et al., 2006). A variety of data products are publicly available from the AIRS instrument data processing system. AIRS is one of several data sets produced by the NASA A-Train constellation of satellites (Parkinson, 2003).

This document is intended to provide an overview of important aspects of the AIRS observing system, including instruments, data processing, and the data sets produced by this system. 'AIRS' commonly refers to a suite of instruments that includes the AIRS instrument and two microwave sounders (Advanced Microwaves Sounding Unit, or AMSU, and the Humidity Sounder for Brazil, or HSB). In addition to instruments, the AIRS mission includes several data processing algorithms, implemented as software in a data processing system. The calibration processing system produces calibrated radiances observed along an orbit track (see Figure 1 below), referred to as Level 1B data. The software implementation of the retrieval algorithms produces geophysical quantities at Level 1B locations, such as atmospheric temperature structure. Retrieved quantities are referred to as Level 2 data. Geophysical quantities reported on regular space-time grids are referred to as Level 3 data.

The algorithms and data sets described here were created by the AIRS Science Team (though other algorithm efforts are also discussed below). Development of the Science Team algorithms began prior to the launch of Aqua and these algorithms have been updated regularly. These updates are motived by improvements in algorithm performance, but also made necessary by the failure of HSB early in the mission and by degradation of some AMSU channels. As of mid-2020, AIRS Level 2 processing is at Version 7; the first data release in 2003 was Version 3. The AIRS system produces three distinct Level 2 data sets: a five month AIRS/AMSU/HSB record, a 14 year AIRS/AMSU record, and a complete AIRS-Only record. Most algorithm development effort has gone into Level 2 because it is a large and complex system. Also, the resulting geophysical quantities (e. g., atmospheric temperature and water vapor) are fundamental to theoretical and model depictions of the atmosphere, and are thus often easier to interpret than are calibrated radiances. This interpretation is aided by a quality control information about retrieved quantities. Many AIRS quantities have been extensively tested and validated against other observations.

Data sets produced by the AIRS processing system are the fundamental output of the AIRS mission so they are described in detail below. The AIRS data sets are both varied and detailed, so a set of documents describing their structure and validation status is also outlined here. Appendix B provides a set of sample readers.

2 The Aqua Spacecraft and Orbit

The Earth Observing System (or EOS) Aqua spacecraft was launched into a polar sun-synchronous orbit on 4 May 2002. The AIRS instrument suite is one of several instrument systems onboard Aqua (Parkinson, 2003). Here are some numbers describing the Aqua orbit:

- The orbit period is 98.8 minutes. The spacecraft equatorial crossing local times are 1:30 in the morning (descending, or southward moving) and 1:30 in the afternoon (ascending).
- Its repeat cycle period is 233 orbits (16 days) with a ground track repeatability of +/- 20 km.
- The nominal orbital altitude is 705 km, with an inclination 98. 20° relative to the equatorial plane when viewed from the direction of the sun.

The Aqua spacecraft is expected to remain in normal operations until late 2022, at which time it will be begin drifting to a later local time. Sometime after 2025 the Aqua will be deliberately de-orbited to minimize the risk of falling debris.

Aqua orbital track information can be found here:

http://www.ssec.wisc.edu/datacenter/aqua/

Aqua overpass predictions are available here:

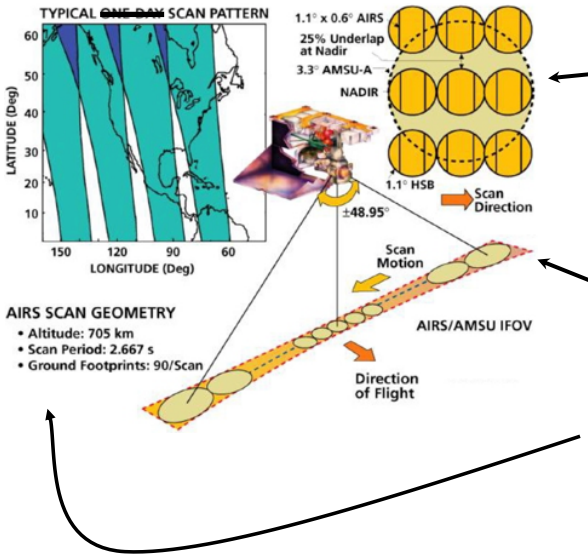
https://oceandata.sci.gsfc.nasa.gov/cgi/overpass_pred

3 The AIRS Instrument Suite: AIRS, AMSU and HSB

At launch the AIRS suite included a hyperspectral infrared instrument (AIRS) and two multichannel microwave instruments, the Advanced Microwave Sounding Unit-A (AMSU-A or AMSU) and the Humidity Sounder for Brazil (HSB). The AIRS instrument includes an imaging radiometer in four visible and near-infrared bands. HSB stopped operating on 5 February, 2003, but an AIRS/AMSU/HSB product has been available in all data releases. The AIRS/AMSU/HSB viewing geometry is shown in Figure 1.

Any combination of AIRS, AIRS/AMSU and AIRS/AMSU/HSB are commonly referred to as “AIRS products” with “microwave-only” referring to products retrieved only from HSB and AMSU radiances. The main source of information in the AIRS retrieval system is infrared radiances. Figure 2 gives an example of a single simulated AIRS infrared spectrum. Examples of observed AIRS, AMSU, and HSB spectra are shown below.

In addition to loss of HSB in 2003, the AIRS observing system has been affected by the steady loss of some AMSU channels. These changes in microwave radiance information have necessitated the development of an AIRS-Only retrieval algorithm.



1. AMSU footprint, 45 km across at nadir, contains 9 AIRS spectra
   - THIS IS THE RETRIEVAL GRANULARITY.
2. Viewing swath 30 AMSU footprints or ~1650 km wide.
3. The result: 2,916,000 IR spectra and 324,000 retrievals per day

Figure 1. AIRS, AMSU and HSB observations within a single AMSU footprint, and within an orbital swath.

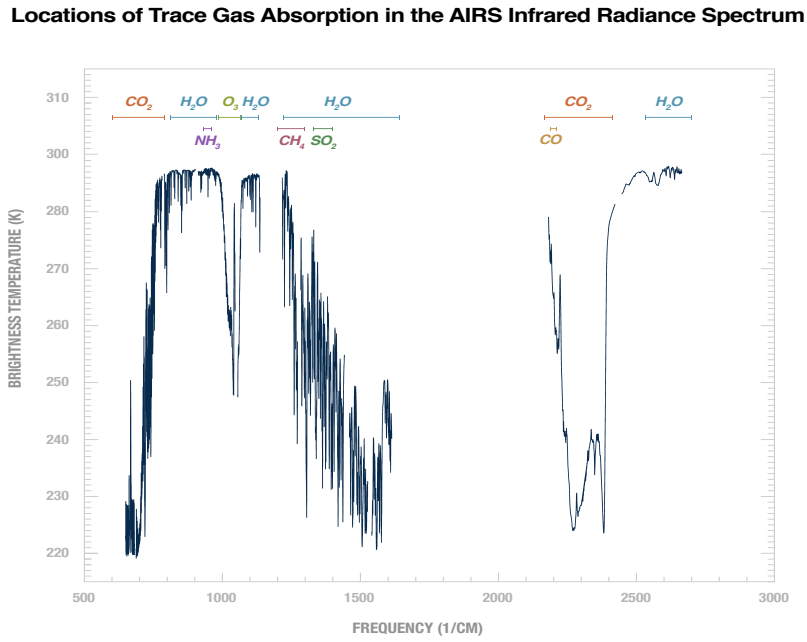


Figure 2. Simulated AIRS spectrum with prominent spectral features marked.

Here are some numbers describing AIRS/AMS/HSB viewing characteristics:

- AMSU viewing footprints are about 45 km wide at nadir, in a swath 30 footprints wide. Each AMSU scene footprint contains nine AIRS and HSB footprints, each about 15 km across at nadir. See the upper right part of Figure 1 for the instrument viewing geometry.
- AMSU footprints are sampled 15/4 or 3.75 times per seconds, so AMSU observe 324,000 footprints per day.
- AIRS and HSB sample at nine times higher rates than AMSU, or 135/4 or 33.75 footprints per second, or 2,916,000 footprints per day each.

The AIRS Instrument

AIRS is a continuously operating cross-track scanning infrared sounder, consisting of a telescope that feeds an echelle spectrometer. The AIRS spectrometer acquires 2378 spectral samples at resolutions, $\lambda/\Delta\lambda$, ranging from 1086 to 1570, in three bands: 3.74-4.61 μm (2169-2674 cm^{-1}), 6.20-8.22 μm (1217-1613 cm^{-1}), and 8.8-15.4 μm (649-1136 cm^{-1}). The coverage gaps are apparent in Figure 2. The scan mirror operates at approximately 265 K, due to radiative coupling to the Earth and space, and to the 150 K IR spectrometer. The infrared focal plane is cooled to about 58 K by a Stirling/pulse tube cryocooler. Cooling of the infrared optics and detectors is necessary to achieve the required instrument sensitivity. The AIRS instrument is described in detail in (Morse et al, 1999).

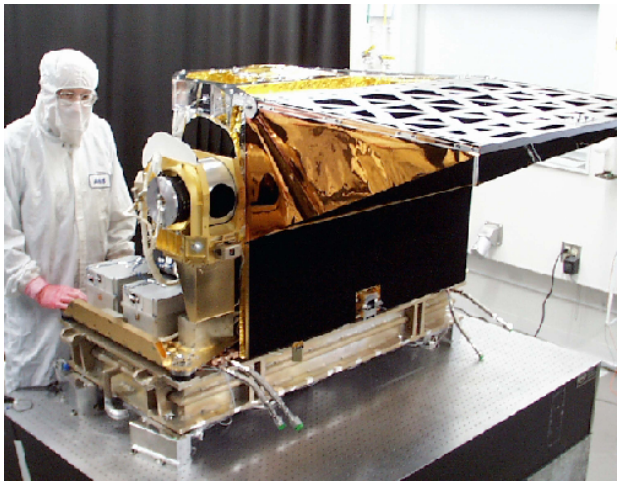


Figure 3: The Atmospheric Infrared Sounder (AIRS) shown at BAE SYSTEMS prior to delivery for spacecraft integration.

The fields of view of the infrared channels have a solid angle width about 1.1 degrees in diameter, which corresponds to about 15 km in the nadir. These are the smaller circles in Figure 1. During each scan, the rotating external mirror observes the underlying Earth scene from 49.5° on one side of the nadir to 49.5° on the other side, in 90 steps, obtains two additional views of dark space (one before and one after the Earth scene), one view of an internal radiometric calibration target, and one view of an internal spectral calibration target. Thus, each scan produces 94 sets of measurements (90 earth scenes and 4 calibrations). The scan is repeated every 8/3 seconds. The downlink data rate from the AIRS instrument is 1.2 Mbit/sec.

The stable and precise radiometric performance of the AIRS instrument is the foundation of the AIRS data record. The Noise Equivalent Temperature Difference (NEdT) for AIRS ranges from 0.1K to 0.8K for individual channels,

with a radiometric accuracy of better than 250 mK (one standard deviation) in most channels (Pagano et al., 2020). The AIRS radiances at the 1231 cm^{-1} window channel show excellent stability relative to independent SST estimates, with a drift of less than 0.2–0.3 milliKelvin per decade, from 2002 to 2019 (Aumann et al., 2019). The spatial response functions of each AIRS channel were measured pre-flight and showed uniform response for most channels. Channels near the ends of detector modules have sufficiently different response that they can impact radiometry in non-uniform scenes (see Pagano et al., 2015). The AIRS spectrum is calibrated to better than 1 ppm (roughly 0.001 cm^{-1}) using absorption features in the upwelling spectrum, and spectra are corrected for time varying spectral calibration, including Doppler shifts from Earth's rotation (Strow et al., 2006; Pagano et al, 2020). Spectral calibration data are provided separately in calibration properties files by epoch. Corrections to the spatial nonuniformity and spectral drifts, along with cleaned and gap filled radiances (using principal component reconstruction) are available in a new Level 1C product. The Level 1C product resamples the spectra to a common set of frequencies for the entire mission. More information is found in the AIRS Level 1B, and Level 1C user guides.

The Visible/Near-Infrared Imager on AIRS

In additional to a spectrometer, the AIRS instrument includes a Visible/Near-Infrared (Vis/NIR) imaging photometer with four spectral bands, each with nine pixels along track. Optical filters in the 400 nm to 1000 nm region to determine the four spectral bands. The Vis/NIR detectors are not cooled and operate in the 293 to 300 K ambient temperature range of the instrument. The pixel fields of view subtend a solid angle 0.185 degree wide, for a spatial resolution at nadir of 2.3 km. AIRS obtains eight cross-track samples of each Vis/NIR detector as the mirror sweeps across one of the 90 AIRS footprints in a scan. The Vis/NIR imager is coaligned with the infrared spectrometer to enable simultaneous measurements of the Vis/NIR and infrared scene. The Vis/NIR channels provide diagnostic support to the infrared retrievals by detecting low clouds or highly variable surface features within the infrared field of view (Broberg et al., 2017).

The AMSU-A Instrument

AMSU-A is a 15-channel microwave sounder implemented as two independently operated modules. Module 1 (AMSU-A1) has 12 channels in the 50 to 58 GHz oxygen absorption band. These provide the primary temperature sounding capabilities at microwave frequencies. A channel at 89 GHz provides surface and moisture information. Module 2 (AMSU-A2) has 2 channels, at 23.8 GHz and 31.4 GHz, which provide surface and moisture information (total precipitable water and cloud liquid water). Like AIRS, AMSU-A is a cross-track scanner. The three receiving antennas (two for AMSU-A1 and one for AMSU-A2) are parabolic focusing reflectors mounted on a scan axis at a 45° tilt angle, so that microwave radiation is reflected from a direction along the scan axis (a 90° reflection). AMSU-A scans three times as slowly as AIRS (once per 8 seconds) and its footprints are approximately three times larger than those of AIRS (an angular

width of about 3.3 degrees, or 45 km at nadir). This results in three AIRS scans per AMSU-A scan and nine AIRS footprints per AMSU-A footprint.

AMSU Performance History

Some AMSU channels have been slowly losing sensitivity, and AMSU A-2 failed entirely in 2016. Here is a summary of AMSU performance issues over time:

- AMSU channel 4 failed 1 October 2007 with radiances useful until mid-2007.
- AMSU channel 5 progressively degraded beginning January 2010.
- AMSU channel 7 exhibits abnormal noise levels and should not be used.
- AMSU-A2 with its channels 1 and 2 failed on 24 September 2016.
- AMSU channel 14 scene temperature underwent a sudden drop in brightness temperature of about 4 K on 21 June 2018 but recovered, with temperatures increasing by about 4 K on 19 June 2019. The cause is not known.

The HSB Instrument

The Humidity Sounder for Brazil (HSB) is a 4-channel microwave moisture sounder implemented as a single module. Three channels are located near 183 GHz, while the fourth is a window channel at 150 GHz. HSB is nearly identical to the AMSU-B instruments operated by NOAA on its operational weather satellites, but HSB lacks the fifth channel (89 GHz) of AMSU-B. HSB has a single parabolic scan antenna, and like AIRS and AMSU is a cross-track scanner. Its scan speed and viewing footprint are similar to AIRS, giving one HSB footprint per AIRS footprint and nine per AMSU footprint. HSB ceased operation on February 5, 2003 due to a failure in the mirror scan motor electronics.

4 Observing Geometry, Data Granules and Sample Radiance Observations

Day and Night: Ascending and Descending Node Observations

The northward moving part of the sun-synchronous Aqua orbit is commonly referred to as ‘ascending node’. This is the sunward-facing part of Earth, so most ascending node data are in daytime. Exceptions occur near the poles away from the equinoxes, when parts of the ascending node are in the Earth’s shadow. Similarly, most descending node observations are taken at night. All AIRS granules are labeled as either ascending, descending, or transitional (a combination of ascending and descending at the highest latitudes). Because of this nearly complete day-night distinction, Level 3 data are reported as ascending node, descending node, or both nodes combined.

Instrument Timing and Six Minute Time Granules

AIRS data obtained along the viewing swath are archived in ‘granules’ representing six minutes of wall-clock time. Six minutes was chosen because it is the smallest integer number of minutes where AIRS, AMSU, and HSB all take an integer number of scans. In six minutes AMSU takes 45 scan sets of 30

across-swath footprints, while AIRS and HSB scan at three times this rate for 135 across-track scans, each containing 45 of their fields of view. This definition of granule time is convenient because it divides evenly into ten granules per hour and 240 granules per day. However, orbits contain non-integer numbers of granules.

Figure 4 illustrates the locations of all AMSU footprints over western Mexico and the United States that make up Granule 209 on September 6, 2002. Since the granule is from an ascending, or daytime, part of the orbit, the spacecraft track tends toward the northwest. Nighttime orbits are aligned in a south-southwesterly direction. As Figure 1 shows, the scan direction on Earth as seen from the Aqua spacecraft and facing the direction of motion is left to right.

Figure 4: AIRS/AMSU/HSB Footprint Pattern Sept 6, 2002; Granule 209

Figure 5 shows all the AIRS data granule locations from 1 February 2013. Granule locations vary with time, though repeat every 16 days, but with ~7 km shifts when leap seconds occur.

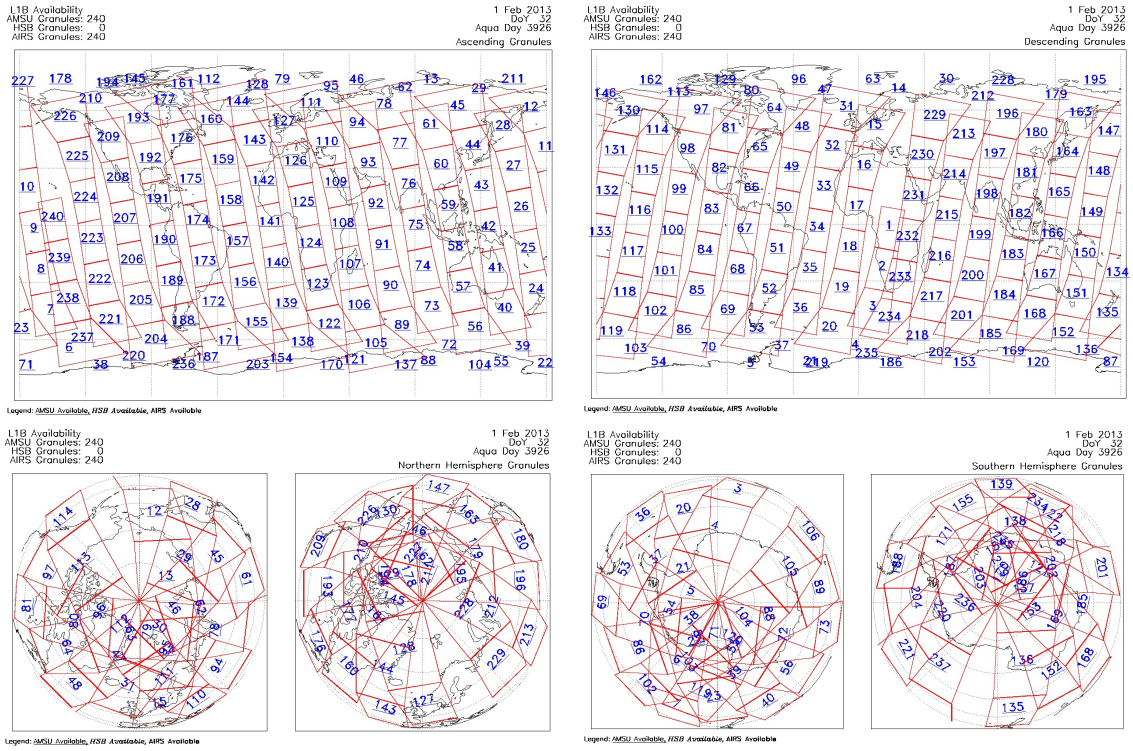


Figure 5: AIRS/AMSU/HSB Granules for 1 February 2013

Top left: ascending granules

Top right: descending granules

Bottom left: Arctic granules

Bottom right: Antarctic granules

Examples of AIRS/AMSU/HSB and Vis/NIR Imagery

As shown in Figure 1 and discussed above, each AMSU-A footprint encompasses 9 AIRS and HSB footprints arranged in 3 by 3 grids. This arrangement is illustrated further in Figure 6, which was produced from the AIRS geolocation information for September 6, 2002, just off the coast of Southern California. The large circle represents the 3.3 degree solid angle width (not geographic size) footprint of an AMSU-A observation. The smaller colored circles represent the 1.1 degree footprints of the associated arrays of AIRS and HSB observations. The colored rhombuses represent the areas covered by the associated arrays of Vis/NIR pixels.

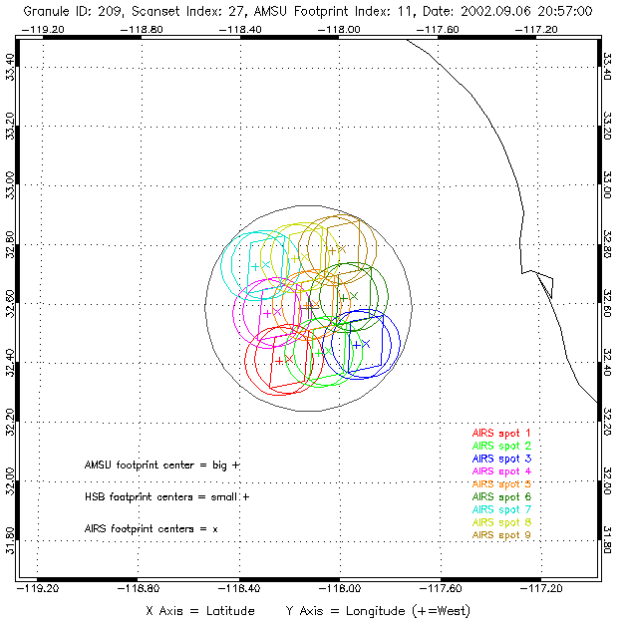


Figure 6: AIRS/AMSU/HSB Footprint Pattern Sept 6, 2002; granule 209; AMSU scanline 27; footprint 11, central (lat,lon) = (32.6°, -118.1°), just west of San Diego, California.

Figure 7 shows the combined AMSU and HSB spectra for the example scene shown in Figure 6. Channel number is shown along the vertical axes (AMSU to the left and HSB to the right), and the horizontal axis represents brightness temperature. The AMSU temperature sounding channels (3-14) are connected with line segments, and that plot can be viewed as a rudimentary representation of the temperature profile. The lowest channel is affected by the surface, however, which depresses the brightness temperature relative to the atmospheric temperature for this oceanic scene. AMSU channels 1, 2 and 15 are plotted separately as bars in Figure 7, since they are window channels that are primarily influenced by the surface brightness (i.e. the product of surface temperature and emissivity). Ocean emissivity is very low for channels 1 and 2, which causes very low brightness temperatures, even though the SST is relatively high. Channel 1 is warmer than channel 2 because it is affected by water vapor and clouds, which elevates the brightness temperature over the apparent cold ocean background. Channel 15 is warmer still, due to a higher emissivity as well as higher sensitivity to both water vapor and clouds.

HSB has four channels, and of its nine fields of view within the single AMSU field of view, resulting in the nine line plots shown to the right in Figure 7. The vertical order of the channels reflects the order of altitude of the maximum radiance source (peak of the weighting function) rather than the serial channel number. These channels essentially reflect the atmospheric temperature near the peaks of the water vapor/liquid weighting functions. The lowest channel (#2)

peaks near the surface (but has slightly lower brightness temperature than the surface due to the emissivity). The highest channel (#3), which is too opaque to have much influence from the surface, has a brightness temperature somewhere between AMSU channels 4 and 5, which suggests it peaks at perhaps 850 mb. The spread between the nine plots suggests there is some (but not much) variability in water vapor and liquid water in the scene.

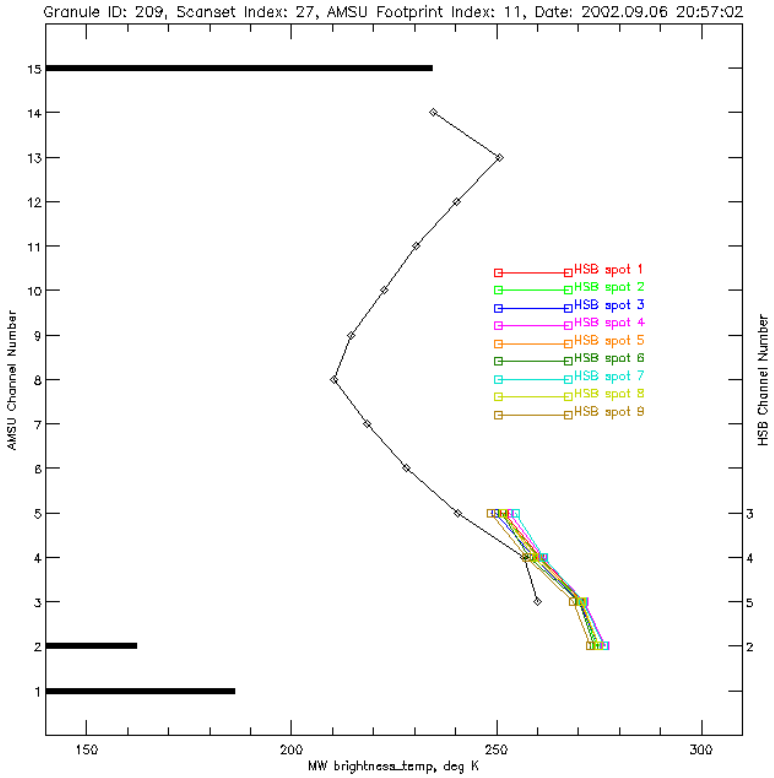


Figure 7. Microwave Radiances (AMSU-A and HSB) Sept 6, 2002; granule 209; scanline 27; footprint 11

Figure 8 shows the nine AIRS infrared radiance spectra from the example scene in the previous figures. The brightness temperature in the 900 cm^{-1} region varies from about 260 K to 290 K. The spectra are obtained over ocean so conditions are relatively uniform, with the exception of cloud properties. Thus, the variability of brightness temperature in Figure 8 is mostly due to the effect of clouds. Note the slope of the coldest spectrum (color-coded brown) in the 900 cm^{-1} region. Since cloud tops tend to be colder than the surface, this is most likely the cloudiest of the nine AIRS footprints; spectral slope is a signature of cirrus clouds. This spectrum also appears to reflect more short wavelength solar radiance than other AIRS spectra (i.e., higher brightness temperature in the 2600 cm^{-1} spectral region).

Figure 9 is a Vis/NIR image of granule 209, showing the mixed clouds typical of the troposphere.

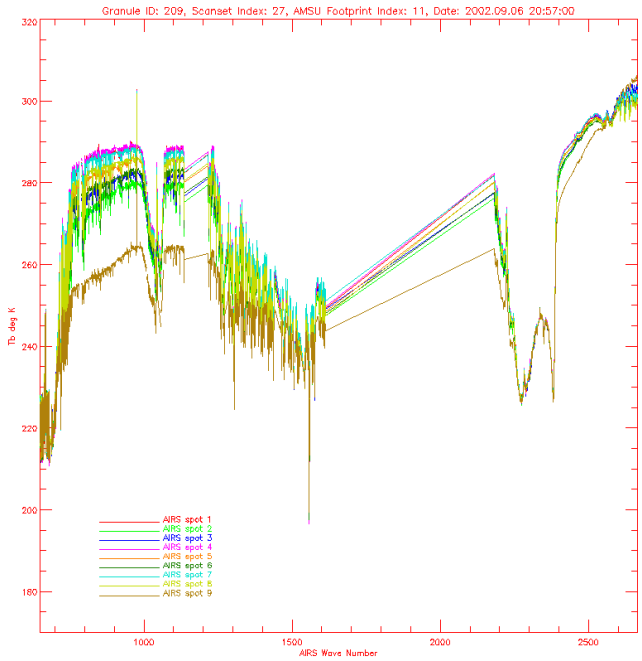


Figure 8. Infrared Radiance Spectra (AIRS)
Sept 6, 2002; granule 209; scanline 27; footprint 11

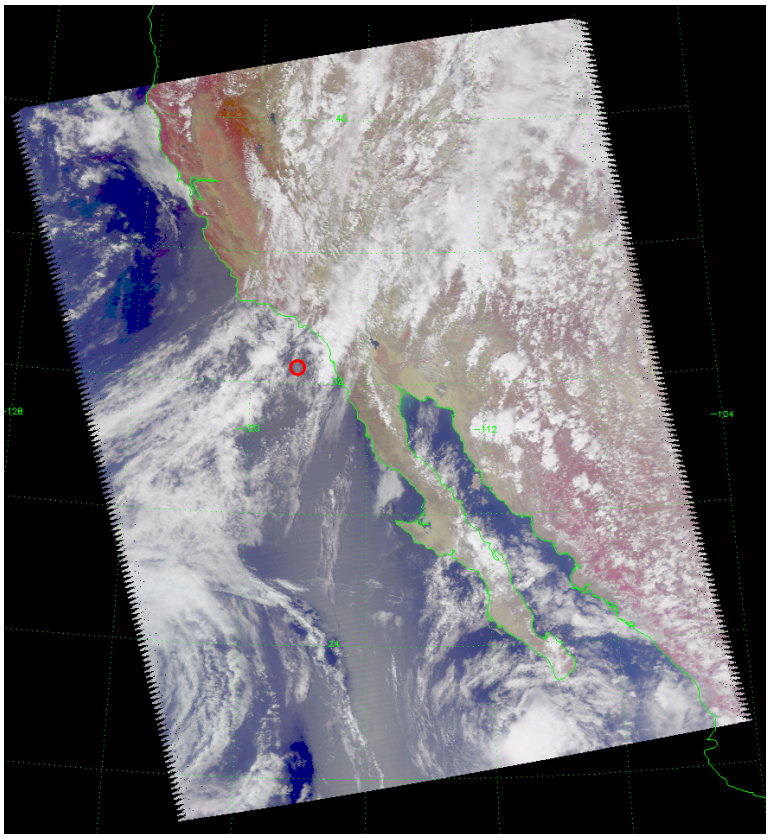


Figure 9. False color image of Sept 6, 2002 Granule 209 constructed from Vis/NIR radiances. The red circle shows the approximate outline of the example AMSU field of view from the previous three figures.

5 AIRS and other hyperspectral infrared sounders

AIRS is one of a constellation of eight hyperspectral infrared sounders, as listed in Table 1. All have broadly comparable spectral resolution and coverage, and their retrieved quantities are similar. A major goal of the NASA sounder science is to provide a unified data set from these instruments. All sounders in Table 1 except TES on Aura are co-aligned with microwave instruments.

The NASA-supported CLIMCAPS Level 2 algorithm was developed to process data from instruments on multiple satellites. CLIMCAPS currently operates on AIRS, CrIS on S-NPP, and CrIS on NOAA-20 (JPSS1) listed in Table 1. See Smith and Barnet (2020) for the AIRS/AMSU version of the CLIMCAPS data set. These data are currently available at the NASA GES/DISC for the Suomi-NPP satellite and the JPSS-1 satellite. The Aqua CLIMCAPS retrieval product will be available at the NASA GES DISC in late calendar year 2020. Additional retrieval algorithms have been developed for AIRS, and associated publications are available on the AIRS website.

Instrument / Spacecraft	Record Extent	Sponsoring Agency
AIRS / Aqua	18 years: Aug 2002 - present*	NASA
IASI / MetOp A	14 years: Oct 2006 - present*	EUMETSAT
TES / Aura	14 years: Jul 2004 - Jan 2018	NASA
CrIS / Suomi-NPP	8 years: Oct 2011 - present*	NASA and NOAA
IASI / MetOp B	8 years: Sep 2012 - present*	EUMETSAT
CrIS / NOAA-20	2 years: Feb 2018 - present*	EUMETSAT
IASI / MetOp C	1 year: Nov 2018 - present	EUMETSAT
HIRAS / FengYun 3D	Nov 2017 – present*	Chinese Met. Admin.

*As of May 2020.

Table 1. Orbiting hyperspectral infrared sounders. AIRS became the first such instrument with the launch of Aqua on 4 May 2002.

6 AIRS and Model Reanalysis Data Sets

Many of the quantities produced by AIRS Level 2 processing, such as temperature and water vapor vertical structure, are also available as weather and climate model output, and as model reanalyses. Many reanalysis systems assimilate AIRS radiances. Consequently, much of the information from AIRS is incorporated in reanalysis data. Also, reanalysis data are reported synoptically, on regular space-time grids. This simplifies their use, especially compared to AIRS Level 1 and Level 2 products. The primary advantage of AIRS retrievals over reanalyses is that AIRS observations preserve instantaneous relationships between quantities like temperature, water vapor, and cloud. In reanalysis

systems, these relationships are affected by both the physical models embedded in the systems and by assimilated observations. As a result, reanalysis features are often roughly correct, but with details misplaced in space and time. Also, the uncertainties introduced by the model and assimilation process are often difficult to quantify. The primary disadvantage of the AIRS system is incomplete sampling because infrared sounding is limited to regions of thinner clouds. In addition, the AIRS retrieval algorithm has its own challenges in quantifying uncertainties in inferred geophysical quantities.

The tradeoffs between direct AIRS observations and model reanalyses are complex and beyond the scope of this document. Interested readers are encouraged to examine the peer-reviewed publications on the AIRS web page at https://airs.jpl.nasa.gov/ for additional information.

7 Data Processing Steps

This is a brief overview of AIRS processing. Several documents provide many additional details, as described in Section 9 below.

Geolocation and Level 1A data

AIRS data processing begins with receipt of Level 0 instrument counts. Once the Level 0 data are organized, algorithms perform geolocation refinement and conversion of raw data numbers to engineering units (DN to EU). Finally, the level 1A data are collected into granules. *Level 1A products are archived but not publicly available.*

Calibration of Level 1B and 1C radiances

Calibration processing uses baseline measurements from an on onboard calibration source and from space views to convert instrument units into physical radiance units. AIRS, AMSU and HSB calibrated radiances are also geolocated, using known spacecraft orientation and instrument pointing characteristics. Calibrated and geolocated radiances are archived as Level 1B (L1B) files (see Table 3 below). The calibration algorithms are generally simpler than the retrieval algorithm, and calibration software has been updated less frequently than retrieval software. *Note: The L1B radiances will not be reprocessed in Version 7. The algorithm has remained unchanged, and so radiances are still Version 5*.

A new release of the AIRS Level 1C (L1C) product (Version 6.7) resamples the AIRS L1B to a common frequency set, fills spectral gaps, and removes obvious radiometric outliers related to co-registration errors (Manning et al., 2019). The L1C algorithm uses principal component reconstruction (PCR) to adjust the radiances to be more representative of what would be expected without spatial errors. Using the L1C algorithm will result in lower errors for problematic channels in individual spectra. However, SI-traceability of the radiances for L1C is more complex due to the use of the PCR, and Level 1C uncertainties have not yet been estimated.

Retrieval of Level 2 data from Level 1B radiances

The AIRS retrieval systems include a set of software packages to invert AIRS-Only, AIRS/AMSU and AIRS/AMSU/HSB radiances into estimates of geophysical state, referred to as Level 2 (L2) products. (As discussed above, the AIRS retrieval algorithm has three different configurations to accommodate the loss of HSB and the degradation of some AMSU channels; see Figures 10 and 11.) Retrieved quantities include surface temperature and emissivity, profiles of temperature and water vapor, trace gas amounts, and cloud top properties, as listed in Table 2. Note that the table does not include a large number of quality control flags for retrieved quantities.

Level 1B: Observed Radiances	Physical Characteristics	Product Resolution
AIRS Radiances	Upwelling infrared radiances at spacecraft	AIRS
AMSU Radiances	Upwelling microwave radiances at spacecraft	AMSU
HSB Radiances	Upwelling microwave radiances at spacecraft	HSB (AIRS)
Visible/Near Infrared	Images in Vis/NIR	2.3 km grid over AIRS footprints
Level 2: Retrieved Quantity		
Cloud Cleared IR Radiance	Spectrally resolved radiance from cloud-free part of AMSU scene.	AMSU
Sea Surface Temperature	Surface property	AMSU
Land Surface Temperature	Surface property	AMSU
Spectrally Resolved Land Surface Emissivity	Surface property	AMSU
Temperature Profile	Height-resolved, surface to mesosphere	AMSU
Water Vapor Profile	Height-resolved, surface to upper troposphere	AMSU
Total Precipitable Water	Total water in retrieved water vapor profile	AMSU
Effective Cloud Fraction (product of areal coverage and gray cloud emissivity)	Cloud top property	AIRS
Cloud Top Height	Cloud top property	AIRS
Cloud Top Temperature	Cloud top property	AIRS
Cloud Phase	Cloud top property	AIRS
Cloud Effective Radius	Cloud top property	AIRS
Ozone Profile	Height-resolved, upper troposphere to mesosphere	AMSU
Total Ozone	Total ozone in retrieved ozone profile	AMSU
Carbon Monoxide	Amount in middle troposphere	AMSU
Methane	Amount in middle to upper troposphere	AMSU
Outgoing Longwave Radiation	Radiative flux derived from spectrally resolved radiances.	AMSU
Carbon Dioxide	Mid-troposphere amount	3x3 AMSU

Table 2. AIRS Level 1B and Level 2 quantities.

The retrieval process includes a forward radiance model and has three basic steps:

1. *First guess.* An initial estimate of geophysical state. For AIRS Version 7 this is neural network data set trained on several days of model reanalyses. The AIRS retrieval problem is ill posed so several solutions may satisfy the observed radiances. The AIRS Version 6 and 7 retrieval algorithms use a neural network to obtain a reasonable initial estimate of geophysical state. Version 5 and earlier versions used a regression algorithm
2. *Cloud clearing.* An estimate of the clear-scene AIRS radiance within an AMSU footprint containing a 3x3 set of AIRS (and possible HSB) spectra; see Figures 1 and 8. This process is effective for clouds whose mean optical is roughly unity or less over the 3x3 AIRS footprint set. Cloud clearing does not require entirely clear scenes to be effective, but does require differences in clouds between AIRS fields of view within the 3x3 set.
3. *The physical retrieval.* Refinement of the first guess to give an improved estimate of geophysical state, such that radiances modeled on that estimate are a best fit to cloud cleared radiance.

Although steps 2 and 3 are listed sequentially here, they are performed iteratively by the AIRS algorithm.

The AIRS retrieval algorithm is described in greater detail in Susskind et al. (2003; 2011), and in the Algorithm Theoretical Basis Document (**L2 ATBD**), with most recent updates in the latest testing report (**V7 L2 Performance Test and Validation Report)**.

Vertical Representation: Levels and Layers

The AIRS Level 2 retrieval estimates mean water vapor, ozone, carbon monoxide, and methane in 100 layers. AIRS products prior to Version 6 reported only column totals and layer-mean amounts for these gases. Version 7 Level 2 Standard and Support Products for these gases are also reported as level products (values at the specific pressure level upon which they are reported).

The level quantities are derived from the internal 100-layer quantities by a smoothing spline, tuned to convey information content and atmospheric variability. Please see **V7 L2 Levels Layers Trapezoids** for further details.

Level 2 and Level 3 Standard and Support Products and Vertical Resolution

The fundamental output of AIRS retrieval system is Level 2 profile quantities containing 100 vertical levels. This resolution is used because the AIRS radiative transfer model –the rapid transmittance algorithm, or RTA–, embedded in the retrieval requires fine vertical resolution for numerical stability. However, this vertical resolution is significantly higher than that needed to convey the information content of the input spectra. This led to the creation of basic two AIRS Level 2 and Level 3 data products: Standard and Support, as shown in Figure 11:

- *Standard Products* are reported at pressure levels of 1100, 1000, 925, 850, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, 15, 10, 7, 5, 3, 2.0, 1.5, 1.0, 0.5, 0.2 and 0.1 hPa. This reduced resolution better reflects the true information content. Standard products are intended for most data users as they embody the majority of the information in the retrieval.
- *Support Products* are reported at the native retrieval resolution of 100 levels. Their intended uses include calculation of radiances via the AIRS RTA, the calculation of level quantities from layer quantities, beta testing future products and for investigation of the operation of the retrieval algorithm, or analyses of vertical information content. The AIRS averaging kernels (measures of information content) are included in the Support products.

Gridding of Level 2 data to produce Level 3 mapped quantities.

As can be seen in Figure 1, the Aqua orbit tracks are not aligned in a north-south direction. Also, the sun-synchronous Aqua orbit means that most locations are sampled twice per day, but with different sampling times for different longitudes. To simplify interpretation of retrieved quantities, Level 3 (L3) products include summary statistics of geophysical parameters reported on a 1°x1° grid cells over -180.0° to +180.0° longitude and -90.0° to +90.0° latitude, reported daily and calendar monthly. Level 3 data products are separated into ascending and descending portions of the orbit. Days in AIRS Level 3 products do not span noon to midnight. Instead, the daily time step is chosen so that the longitude range -180 to 180 is covered in exactly 24 hours.

8 Data Organization

Levels 1, 2 and 3 Processing Flow and Data Sets

The fundamental resolution of the AIRS data products is defined by the fields of view of the instruments going into the products, as shown in Table 2. The output of Level 1B, Level 2 and Level 3 processing is organized into data products available as computer-readable files. The Level 1B and Level 2 data sets are organized into 240 daily granules, and Level 3 into daily and monthly products as separate ascending node, descending node and combined node. (Level 3 products prior to Version 7 included 8 day averages, or half the orbit repeat cycle.). The flow of data through the processing software is represented schematically in Figures 10-12. Note that ammonia, carbon dioxide, and cloud phase and effective radius (see Table 2) are created by post-processing of the output of the basic Level 2 retrieval algorithm. Level 1C is produced from Level 1B, but is not currently used in producing the Level 2 products.

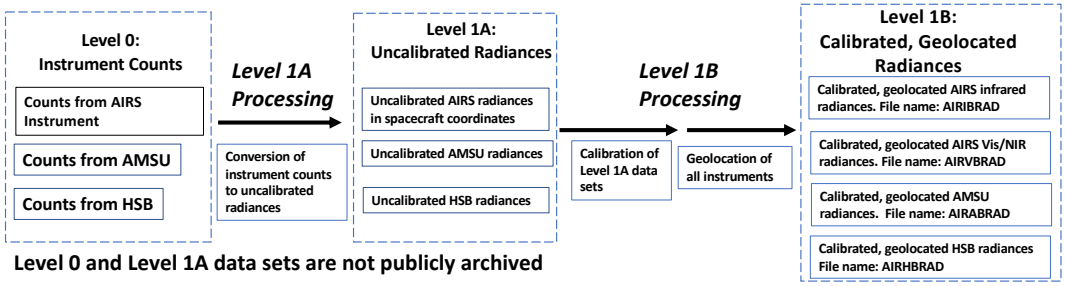


Figure 10. Level 1B processing steps. The product names in Level 1B quantities (AIRSBRAD, etc.) are discussed below.

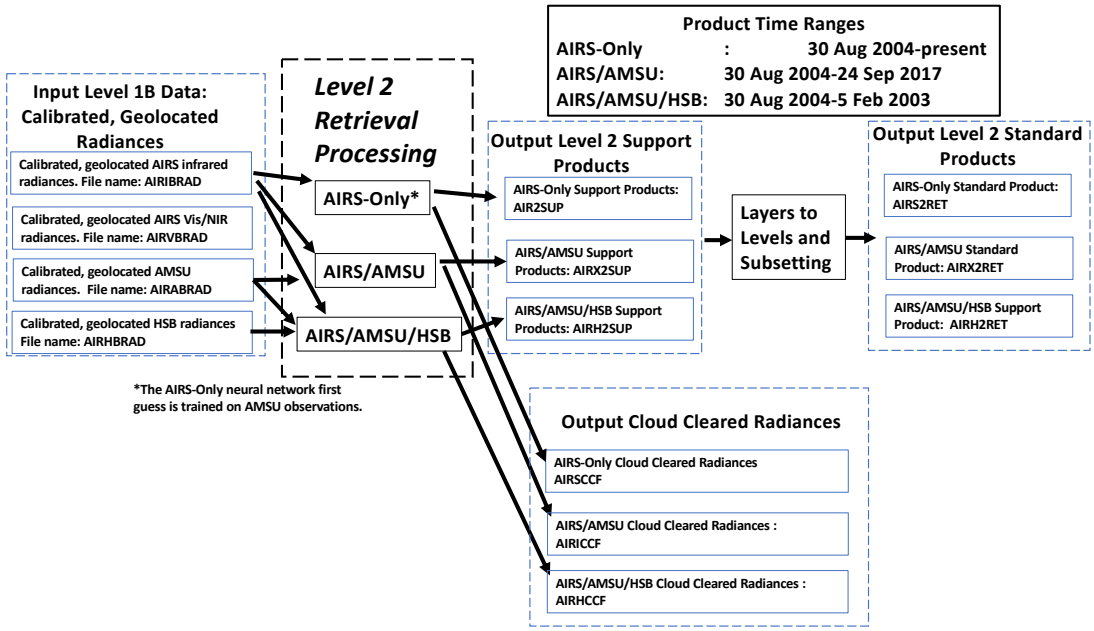


Figure 11. Products created by AIRS Level 2 retrieval processing are within the rectangular boxes, with blue dashed boxes surrounding similar products from different processing algorithms. Cloud cleared radiances are in separate files from other Level 2 products. All quantities in Table 2 are included in the three Level 2 processing types of AIRS-Only, AIRS/AMSU, and AIRS/AMSU/HSB. The product names in Level 2 quantities (AIRS2SUP, etc.) are discussed below in the 'Short Names' section.

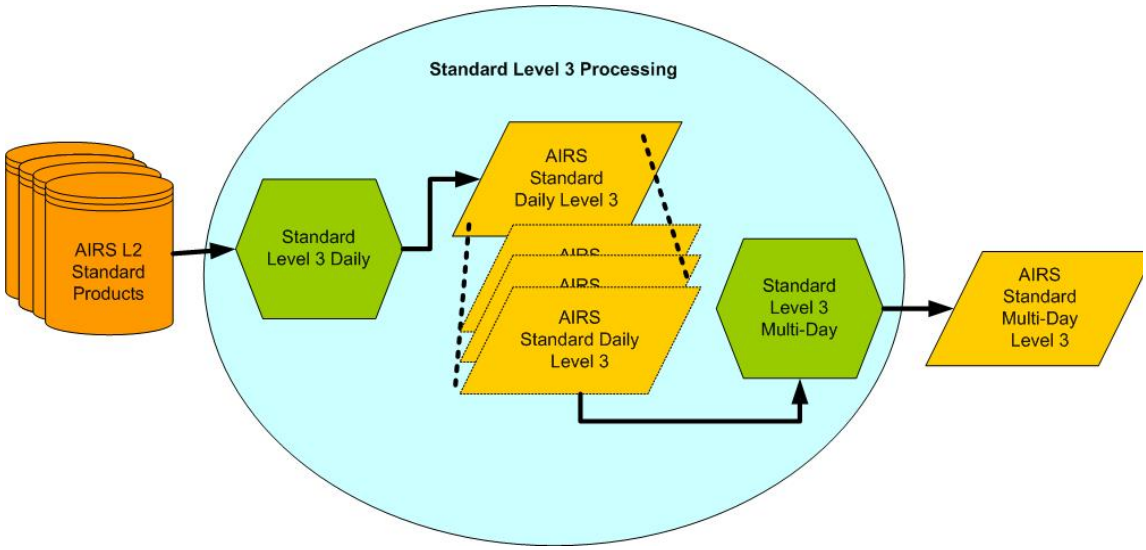


Figure 12: High Level Flow Diagram of AIRS Standard Level 3 Processing

AIRS/AMSU/HSB, AIRS/AMSU, and AIRS-only Level 2 and Level 3 Processing Systems

AIRS Level 2 and Level 3 data are generated by three different processing systems, depending on the combination of AIRS, AMSU and HSB radiances input to the retrieval process, as illustrated in Figure 11. The three different types of Level 2 and Level 3 data are:

- *AIRS/AMSU/HSB:* This is the shortest time series of the three, starting on 30 August 2002 and ending five months later on 5 February 2003 when the HSB instrument stopped working.
- *AIRS/AMSU:* This record is based on combined AIRS and AMSU observations and covers the period 30 August 2002 to 24 September 2016 (about 14 years), when AMSU-A2 failed.
- *AIRS-Only:* This is the main product of the Version 7 retrieval system, first developed for Version 6 processing in anticipation of the loss of some or all AMSU channels. It does not use any microwave data and covers the entire duration of the mission.

Short Names

AIRS data products have a Short Name descriptor that can be used in data searches. Appendix A has details about file naming and a complete list of products. Tables 3, 4, and 5 give the products, their Short Names, and the typical size of individual granules.

Level 1B products are provided from the infrared, visible/near-infrared, and the two microwave instruments. Since the infrared and visible/near-infrared products are large, Quality Assurance (QA) subset products are provided to allow users to prescreen and decide which granules they want.

The standard products of Level 2 and 3 are intended for most users. The support product files are much larger and contain additional variables that are too large for the standard files or have not been rigorously validated. Since the cloud cleared radiances are large in data volume and many users are expected to have little interest in them, they are provided in separate output files.

Radiance Data Set	Short Name	Granule Size
AMSU-A radiances	AIRABRAD	0.5 MB
HSB radiances	AIRHBRAD	1.7 MB
AIRS radiances	AIRIBRAD	56 MB
Vis/NIR radiances	AIRVBRAD	21 MB
AIRS Level 1B QA	AIRIBQAP	5.6 MB
Vis/NIR Level 1B QA	AIRVBQAP	1.1 MB
AIRS Level 1C radiances	AIRICRAD	110 MB

Table 3. AIRS, AMSU and HSB Level 1B products, Short Names, and granule sizes.

Level 2 Data Set	Short Name AIRS/AMSU/HSB	Short Name AIRS/AMSU	Short Name AIRS Only	Granule Size
Cloud-cleared radiances	AIRH2CCF	AIRI2CCF	AIRS2CCF	14 MB
Standard Product	AIRH2RET	AIRX2RET	AIRSRET	3.5 MB
Support Product	AIRH2SUP	AIRX2SUP	AIRS2SUP	25 MB

Table 4. AIRS/AMSU/AMSU Level 2 products, Short Names, and granule sizes.

Level 3 Data Set	Short Name AIRS/AMSU/HSB	Short Name AIRS/AMSU	Short Name AIRS Only	File Size
Daily standard product	AIRS3STD	AIRX3STD	AIRH3STD	~190 MB
Monthly standard product	AIRS3STM	AIRX3STM	AIRH3STM	~200 MB
Daily support product	AIRS3SPD	AIRX3SPD	AIRH3SPD	~245 MB
Monthly support product	AIRS3SPM	AIRX3SPM	AIRH3SPM	~260 MB

Table 5. Level 3 products, Short Names, and file sizes.

Versions

The current version of Level 1B data processing is Version 5. Level 1C data is released under Version 6.7. For Levels 2 and 3, Version 7 is the most current. For this version, significant improvements and modifications have been applied to the AIRS retrieval algorithm, especially the IR-only. A summary of noteworthy changes from Version 6 to Version 7 is provided in the document **V7 Changes from V6**. A more detailed characterization of the differences between Version 6 and Version 7 of various AIRS core data products can be found in the **V7 L2 Performance Testing and Validation Report**. Highlights of Version 7 include:

- Removal of bias in water vapor products
- Algorithm improvements leading to improved temperature, water vapor and ozone products
- Improved Stochastic Cloud Clearing Neural Network first guess
- Removal of ambiguity in surface classification

Data Access

AIRS products are available to the user community via the Goddard Earth Sciences Data and Information Services Center (GES DISC). Data files are provided in HDF-EOS2 format, which is based on the HDF4 version (https://hdfeos.org). The AIRS data products are available by searching on the GES DISC website:

https://disc.gsfc.nasa.gov

Specific datasets can be found through various filters or keyword searches using, e.g., the Short Names given in this document, or by clicking on the links to dataset landing pages that are provided in the tables of data products in Appendix A.

The GES DISC provides additional information about obtaining AIRS data, data formats, and services such as data sub-setting tools. Contact information for further support from GES DISC can be found on the following website:

https://disc.gsfc.nasa.gov/information/documents?title=Contact%20Us

9 Organization of AIRS Documentation

All AIRS documentation can be accessed at the following webpage:

https://disc.gsfc.nasa.gov/information/documents?title=AIRS%20Documentation

The AIRS documentation is mainly organized according to data processing levels. The available documents are listed in Table 6. Documents are here referred to by file names (omitting underscores and file type extensions), that include abbreviated levels (L1B, L1C, L2, L3) and version (V7). This general overview document and level-specific product user guides are intended to be the main documents for most users. Several other ancillary documents are provided that may be important for some users but others may not need.

There are two documents that apply to all AIRS/AMSU/HSB products. The present document, **Overview of the AIRS Mission**, is designed to provide an

overview of AIRS products and orient new and experienced users, giving and pointing to crucial information for data users. **AIRS Data Outages** is a supporting document that provides a history of AIRS suite instrument states and periods where data is unavailable, with short descriptions of the reasons behind the outages (also updated on the AIRS website).

The **L1B Product User Guide** is a collection of useful information for Level 1B data users. It includes a quick start guide to the most basic quality assurance parameters that can be accessed to judge L1B radiance product quality. For Level 1C users the **L1C Products User Guide** is the main document. Several ancillary documents for Level 1 are provided that may not be needed for some users but contain helpful information, in particular for advanced users. Algorithm Theoretical Basis Documents (**ATBD**s) describe the theoretical bases of the algorithms used to obtain the different products and are provided for Level 1C and L1B and each instrument type (infrared, microwave, visible/near-infrared). Files listing various channel properties (**Chan Prop Files**) and calibration properties (**Cal Prop Files**) for all channels are also provided as sets of zipped files. **V5 Cal Subset Quick Start** contains a discussion of the calibration subset radiance product.

For users of Level 2 data, the **V7 L2 Product User Guide** is the main document. It is organized by products, where the material for each product has the same structure and contains references to other relevant documents. For example, a user mainly interested in temperature profiles or ozone products can find most important information in one place in the relevant subsection. A complete list of available fields in the Level 2 data files is provided in an appendix to that document, along with short descriptions.

For users of Level 3 data, the **V7 L3 Product User Guide** is the main document. Since Level 3 products are derived from Level 2 products, users may wish to consult Level 2 documentation for further understanding of the products.

There are several ancillary documents that apply to the Version 7 release of Level 2 and Level 3 products. The main changes introduced in Version 7 are summarized in **V7 Changes from V6**. The **V7 L2 Performance Test and Validation Report** further characterizes the differences between Version 6 and Version 7 of AIRS core data products and includes comparisons to other well validated data sources such as radiosondes, surface station, and satellite measurements. It is mostly focused on Level 2 data products but contains limited results for Level 3 products as well. The **V7 L2 Quality Control and Error Estimation** document describes the various quality indicators and how they are set. It is recommended for all users to familiarize with at least the general sections of that document, and the variable-specific sections as needed.

Other ancillary documents may not be needed for some users but contain helpful information, in particular for advanced users. The **L2 ATBD** (Algorithm Theoretical Basis Document) provides the theoretical foundation for the retrieval of geophysical parameters from AIRS, AMSU and HSB radiance observations. **V7 Retrieval Flow** provides a brief overview of the steps of the Version 7 retrievals, and a comparison between Version 7 AIRS-Only and AIRS/AMSU, and the Version 6 retrieval system. In **V7 Retrieval Channel Sets**, the channels

that are used in each part of the Version 7 physical retrieval and the preceding neural network regression are listed by function (geophysical variables).

V7 L2 Levels Layers Trapezoids contains a discussion of the vertical representation of AIRS Level 2 products. This includes a discussion of levels and layers and procedures to convert between them. Trapezoidal layers are introduced with guidance on how to use averaging kernels to compare AIRS profiles with other profiles. Special considerations regarding the top of atmosphere and the surface in product profiles are also covered. Since some users have difficulty accessing attributes in the data files, tables with the Level 2 and 3 standard and support pressure levels are provided in separate documents, **V7 L2 Standard Pressure Levels**, **V7 L3 Standard Pressure Levels**, and **V7 L2 Support Pressure Levels** (common to L3).

Finally, some documents are provided that provide additional details for specific data products. **V7 L2 Cloud Cleared Radiances** contains a discussion of error estimates and suggested quality control for AIRS Level 2 Cloud Cleared Radiances. For the CO and CH_4 trace gas products, profiles and algorithm to reproduce initial guesses for the AIRS retrievals are given in **V7 CO Initial Guess Profiles** and **V7 CH4 Initial Guess Profiles**.

For additional information, please consult the AIRS public web site:

https://airs.jpl.nasa.gov

Questions may also be submitted at the AskAIRS link here:

https://airs.jpl.nasa.gov/data/support/ask-airs

AIRS data users may register here:

https://airs.jpl.nasa.gov/data/registration

to receive periodical announcements of data features that may impact their research and an occasional newsletter.

General Documents			
Overview of the AIRS Mission			
AIRS Data Outages			
Level 1 Documents		*Level 2 & 3 Documents*	
L1B Product User Guide	**L1C Product User Guide**	**L2 Product User Guide**	**L3 Product User Guide**
Ancillary Documents			
L1B IR ATBD		**L2 ATBD**	
L1B Vis NIR ATBD		**V7 Changes from V6**	
L1B MW ATBD		**V7 L2 Performance Test and Validation Report**	
L1C ATBD		**V7 L2 Levels Layers Trapezoids**	
V5 Cal Subset Quick Start		**V7 L2 Quality Control and Error Estimation**	
Cal Prop Files		**V7 L2 Cloud Cleared Radiances**	
Chan Prop Files		**V7 Retrieval Flow**	
		V7 Retrieval Channel Sets	
		V7 CO Initial Guess	
		V7 CH4 Initial Guess	
		V7 L2 Standard Pressure Levels	
		V7 L2 Support Pressure Levels	
		V7 L3 Standard Pressure Levels	

Table 6. AIRS documentation. Documents are listed by file name (omitting underscores and file type extensions) and are accessible at the AIRS documentation web page. General documents apply to all AIRS suite products, level-specific user guides are intended for the general user of each level product, and ancillary files contain more specific information.

Appendix A AIRS Products and File Names

This section contains summary descriptions and tables with AIRS products, which include Level 1, 2 and 3 standard and support products, near-real-time products, and additional (CO_2 and precipitation) products.

File naming convention

The AIRS product files are named in accordance to the following convention:

AIRS.*yyyy***.***mm***.***dd***.***ggg***.***Lev***.***productType***.v***m.m.r.b***.G***productionTimeStamp***.hdf**

Where:

- yyyy = 4 digit year number [2002 -]
- mm = 2 digit month number [01-12]
- dd = day of month [01-31]
- ggg = granule number [1-240] the ".ggg" only applies to Level 1 and Level 2 data. Level 3 data do not have this field
- Lev=processinglevel["L1A","L1B","L1C","L2",or"L3"]
- productType: see Product Type strings in the tables below.
- m.m.r.b = algorithm version identifier is made up of major version, minor version, release version and build number respectively.
- productionTimeStamp = file creation time stamp. Starts off with a letter G for GES DISC processing facility, followed by yydddhhmmss.
    - yy: year number without century;
    - ddd: day of a year [1-366];
    - hhmmss: hours, minutes and seconds UTC time.

Example of a Level 2 standard file name:

AIRS.2019.01.28.120.L2.RetStd_IR.v7.0.1.0.G20071160428.hdf

The version numbers that appear in the AIRS Product Files are slightly different, depending upon the product due to a staged delivery of processing code to the GES DISC. They are:

- Level 1B AMSU-A and HSB Products: v5.0.0.0
- Level 1B AIRS Products: v5.0.x.0
- Level 1B Calibration Subset Product: v5.0.x.0 is still available. It will be superseded at some point in the future.
- Level 1C: v6.7.2.0
- Level 2 Products:
    - Level 2 IR-Only, AIRS+AMSU and AIRS+AMSU+HSB, standard, support, and cloud-cleared radiance products: v7.0.2.0
    - Level 2 CO2; V5.4.11.0
- Level 3 Products:
    - Level 3 Level 2 IR-Only, AIRS+AMSU and AIRS+AMSU+HSB, standard, and support products: v7.0.3.0
    - Level 3 CO2; V5.9.14.0

Level 1 Products

Geolocated and calibrated radiances. Files contain six-minute granules, generally 240 per day, of data (except the calibration subset which is produced once per day). There are level 1B data files from each instrument in the AIRS suite as well as a quality assurance subset for the infrared and visible instruments and the daily calibration subset. Level 1C data include various enhancements. Unlike all routine products, L1C files are only stored for 30 days.

Product Short Name	Product Type Filename String	Description
AIRIBRAD	AIRS_Rad	AIRS IR geolocated and calibrated radiances
AIRVBRAD	VIS_Rad	AIRS Vis/Near IR L1B geolocated and calibrated radiances
AIRABRAD	AMSU_Rad	AMSU-A1 & AMSU-A2 L1B geolocated and calibrated brightness temperatures
AIRHBRAD	HSB_Rad	HSB L1B geolocated & calibrated brightness temperatures
AIRIBQAP	AIRS_QaSub	AIRS IR L1B quality assurance subset
AIRVBQAP	VIS_QaSub	AIRS Vis/Near IR L1B quality assurance subset
AIRXBCAL	Cal_Subset	L1B Calibration subset for AIRS IR, Vis/NIR, and AMSU-A
AIRICRAD	AIRS_Rad	AIRS IR L1C geolocated & calibrated radiances with corrections for instrument artifacts caused by calibration errors, bad channels, spectral shifts, spectra gaps and spectral overlaps

Level 2 Products

Geophysical products (temperature, water vapor, clouds, trace gases). Files contain six-minute granules, generally 240 per day, of data. There are standard, support and cloud cleared radiance files for three instrument combinations.

Product Short Name	Product Type Filename String	Description
AIRS2RET	RetStd_IR	Standard L2 retrieval product created using AIRS IR-Only
AIRX2RET	RetStd	Standard L2 retrieval product created using AIRS IR, AMSU without-HSB
AIRH2RET	RetStd_H	Standard L2 retrieval product created using AIRS IR, AMSU and HSB
AIRS2SUP	RetSup_IR	L2 retrieval support product created using AIRS IR-Only
AIRX2SUP	RetSup	L2 retrieval support product created using AIRS IR, AMSU without-HSB
AIRH2SUP	RetSup_H	L2 retrieval support product created using AIRS IR, AMSU and HSB
AIRSCCF	CC_IR	L2 cloud cleared radiance product created using AIRS IR-Only
AIRICCF	CC	L2 cloud cleared radiance product created using AIRS IR, AMSU without-HSB
AIRHCCF	CC_H	L2 cloud cleared radiance product created using AIRS IR, AMSU and HSB

Level 3 Products

Gridded statistical summaries of the of the AIRS geophysical variables. The Level 3 products are averaged over daily and monthly time spans for each of the three instrument combinations of Level 2 standard and support products.

Product Short Name	Product Type Filename String	Description
AIRS3STD	RetStd_IR001	L3 daily gridded standard retrieval product using AIRS IR-Only
AIRX3STD	RetStd001	L3 daily gridded standard retrieval product using AIRS IR and AMSU, without-HSB
AIRH3STD	RetStd_H001	L3 daily gridded standard retrieval product using AIRS IR and AMSU, with-HSB
AIRS3STM	RetStd_IR028-RetStd_IR031 (depending upon the month)	L3 monthly gridded standard retrieval product using AIRS IR-Only
AIRX3STM	RetStd028- RetStd031 (depending upon the month)	L3 monthly gridded standard retrieval product using AIRS IR and AMSU, without-HSB
AIRH3STM	RetStd_H028-RetStd_H031 (depending upon the month)	L3 monthly gridded standard retrieval product using AIRS IR and AMSU, with-HSB
AIRS3SPD	RetSpd_IR001	L3 daily gridded support retrieval product using AIRS IR-Only
AIRX3SPD	RetSpd001	L3 daily gridded support retrieval product using AIRS IR and AMSU, without-HSB
AIRH3SPD	RetSpd_H001	L3 daily gridded support retrieval product using AIRS IR and AMSU, with-HSB
AIRS3SPM	RetSpd_IR028-RetSpd_IR031 (depending upon the month)	L3 monthly gridded support retrieval product using AIRS IR-Only
AIRX3SPM	RetSpd028- RetSpd031 (depending upon the month)	L3 monthly gridded support retrieval product using AIRS IR and AMSU, without-HSB
AIRH3SPM	RetSpd_H028-RetSpd_H031 (depending upon the month)	L3 monthly gridded support retrieval product using AIRS IR and AMSU, with-HSB

AIRS Near Real Time Products

The AIRS Near Real Time (NRT) products are available for Level-1B, Level-1C and Level-2 and stored on a rolling archive for 7 days. The AIRS NRT products are only produced for the AIRS-Only flavor and the NRT product files are listed by short name in the following table. Access to the AIRS NRT data is free but requires prior user registration. AIRS NRT products are produced by the same core science algorithms as in the routine science data production, but using predicted ephemeris in place of definitive ephemeris and the NRT processing proceeds whether or not the previous or subsequent Level 1B granules are present or whether the forecast surface pressure is present.

The advantage of NRT data is its fast turnaround time, generally available within 3 hours of observations globally. They can be utilized in regional weather forecast models as well as in support of field campaigns. The differences between the AIRS NRT and Routine products are described in a memo:

Product Short Name	Product Type Filename String	Description
AIRIBRAD_NRT	AIRS_Rad	AIRS IR Level 1B geolocated & calibrated radiances
AIRABRAD_NRT	AMSU_Rad	AMSU-A geolocated & calibrated brightness temperatures
AIRVBRAD_NRT	VIS_Rad	AIRS Vis/Near IR geolocated and calibrated radiances
AIRIBQAP_NRT	AIRS_QaSub	AIRS IR Level 1B quality assurance subset
AIRVBQAP_NRT	VIS_QaSub	AIRS Vis/Near IR quality assurance subset
AIRICRAD_NRT	AIRS_Rad	AIRS IR Level 1C resampled and corrected radiances
AIRS2RET_NRT	RetStd	Level-2 retrieval product created using AIRS IR
AIRS2SUP_NRT	RetSup	Level-2 retrieval support product created using AIRS IR
AIRS2CCF_NRT	CC	Level-2 cloud cleared radiance product created using AIRS IR
AIRXAMAP	GranuleMap	Daily maps that show the locations of the AIRS Level 1 and Level 2 granules

AIRS CO_2 Products

The spatial resolution of the AIRS CO_2 Level 2 products is ~ 90 km x 90 km so the files have dimensions of 15 x 22. The Version 5 CO_2 Level 3 files have 2-degree latitude x 2.5-degree longitude grid boxes (dimensions of those files are 91 degrees latitude x 144 degrees longitude). CO_2 products using AIRS-Only are only provided up to February, 2017. CO_2 products using AIRS+AMSU are only provided up to February, 2012.

Product Short Name	Product Type Filename String	Description
AIRS2STC	CO2_Std	AIRS/Aqua Level 2 Carbon Dioxide (**CO2**) Standard Products (AIRS-Only)
AIRS2SPC	CO2_Sup	AIRS/Aqua Level 2 Carbon Dioxide (**CO2**) Support Products (AIRS-Only)
AIRS3C2D	CO2Std001	AIRS CO2 Daily Level 3 files (AIRS-Only)
AIRS3C28	CO2Std008	AIRS CO2 Eight Day Level 3 files (AIRS-Only)
AIRS3C2M	CO2Std028 to CO2Std031 (depending upon the month)	AIRS CO2 Monthly Level 3 files (AIRS-Only)
AIRX2STC	CO2_Std	AIRS/Aqua Level 2 Carbon Dioxide (**CO2**) Standard Products (AIRS+AMSU)
AIRX2SPC	CO2_Sup	AIRS/Aqua Level 2 Carbon Dioxide (**CO2**) Support Products (AIRS+AMSU)
AIRX3C2D	CO2Std001	AIRS CO2 Daily Level 3 files (AIRS+AMSU)
AIRX3C28	CO2Std008	AIRS CO2 Eight Day Level 3 files (AIRS+AMSU)
AIRX3C2M	CO2Std028 to CO2Std031 (depending upon the month)	AIRS CO2 Monthly Level 3 files (AIRS+AMSU)

Aqua AIRS Level 2G Precipitation Estimate

The precipitation estimate from the AIRS Level 2 Support product is combined into one daily “Level 2G” global grid with dimensions (24x1440x720). The short name is “AIRG2SSD” and the filename string is “L2G.Precip_Est.” Every hour is a "layer" in the daily file, and the resulting spatial grid cell size is 0.25 degree (~25 km). Thus the grid size is made to fit TRMM products. Since the AIRS precipitation is retrieved at the AMSU footprint resolution, which is about 45 km at nadir, many cells in this 0.25-deg grid are empty. The data are stored such that the first line is the South Pole. The geolocation information for every hour-layer is also provided in the file. Further information about this product can be found at the GES DISC dataset landing page:

https://search.earthdata.nasa.gov/portal/idn/search?q=airg2ssd&ac=true.

Appendix B Sample Data Readers

Sample IDL, MATLAB, FORTRAN and C data readers are provided in the zipped files:

http://docserver.gesdisc.eosdis.nasa.gov/repository/Mission/AIRS/3.8_ScienceDataSoftwareTools/IDL_MATLAB_READERS.tar.gz

http://docserver.gesdisc.eosdis.nasa.gov/repository/Mission/AIRS/3.8_ScienceDataSoftwareTools/V6_FORTRAN_C_READERS.tar.gz

B.1 IDL-Based Data Readers

The AIRS Project releases to the broad scientific community sample data readers written in Interactive Data Language (IDL) to facilitate user community use of data products. IDL is an array-oriented data analysis and visualization environment developed and marketed by Research Systems, Incorporated (RSI) of Boulder, Colorado.

The user community must realize that the AIRS Project does not have the resources to support consultation on these readers. They are being provided as an aid to give the user community a leg up in using the data. There is no commitment to provide assistance to the broad user community beyond the release of these readers.

B.1.1 read_airs_swath.pro

The IDL procedure to read AIRS L1B and L2 Product files written in HDF-EOS swath format is provided in the file:

read_airs_swath.pro

FUNCTION NAME:

read_airs_swath.pro

USAGE:

status = read_airs_swath(filename,
content_flag,buffer,[content_list=content_list],[swathname=swathname])

INPUT ARGUMENTS:

- **filename** - The fully qualified path to a Level 1B or Level 2 HDF-EOS swath data file.
- **content_flag** - An integer that specifies the type of data to be extracted, as follows:
  - 0 - an array of the names of all data swaths in the file.
  - 1 - names and values of specified swath's dimension parameters.

- 2 - names and values of specified swath's attribute parameters.
- 3 - names and values of specified swath's data field parameters,
- 4 - an array of the data field names within a specified swath.
- **content_list** [OPTIONAL] - An array of text strings which are the names of specific parameters that will extracted per the content flag choice (Choices 1-3 only). If content_list is left unspecified, the function will retrieve the content on ALL items in the category specified by the content_flag.
- **swathname** [OPTIONAL] - A single text expression which is the exact name of the data swath to be extracted from the granule file. If swathname is left unspecified and there is only one data swath in a file, that swath will automatically be used.

HINT: Run this function with the content_flag=0 option first if you suspect that there are more than one data swath in a granule file. AIRS L1B and L2 Data Products have only one swath in each granule file.

OUTPUTS:

- standard sucess code, stored in **status** in the USAGE description above
  - 0 = success
  - -1 = failure.
- **buffer** - This is a general-purpose data buffer. When content_flag=0 or 4, "buffer' is a single text expression. When the other content_flag options are used, buffer is an IDL structure which has the results expressed as buffer.<item_name> and buffer.<item_value>. HINT: To query these results, type "help,buffer,/struct" after running this function.

HOW TO USE:

See README_Swath_Reader_IDL.txt

B.1.2 read_airs_grid.pro

The IDL procedure to read L3 Product files written in HDF-EOS grid format is provided in the file:

read_airs_grid.pro

FUNCTION NAME:

read_airs_grid.pro

USAGE:

status = read_airs_grid(filename,
content_flag,buffer,[content_list=content_list],[gridname=gridname])

INPUT ARGUMENTS:

- **filename** - The fully qualified path to a Level 3 HDF-EOS grid data file.
- **content_flag** - An integer that specifies the type of data to be extracted, as follows:
  - 0 - an array of the names of all data grids in the file.
  - 1 - names and values of specified grid's dimension parameters.
  - 2 - names and values of specified grid's attribute parameters.
  - 3 - names and values of specified grid's data field parameters,
  - 4 - an array of the data field names within a specified grid.
  - **content_list** [OPTIONAL] - An array of text strings which are the names of specific parameters that will extracted per the content flag choice (Choices 1-3 only). If content_list is left unspecified, the function will retrieve the content on ALL items in the category specified by the content_flag.
  - **gridname** [OPTIONAL] - A single text expression which is the exact name of the data grid to be extracted from the granule file. If gridname is left unspecified and there is only one data grid in a file, that grid will automatically be used.

HINT: Run this function with the content_flag=0 option first if you suspect that there are more than one data grid in a granule file. AIRS L3 Data Products have four swaths in each granule file.

OUTPUTS:

- standard sucess code, stored in **status** in the USAGE description above
  - 0 = success
  - -1 = failure.
- **buffer** - This is a general-purpose data buffer. When the content_flag=0 or 4, "buffer' is a single text expression. When the other content_flag options are used, buffer is an IDL structure which has the results expressed as buffer.<item_name> and buffer.<item_value>. HINT: To query these results, type "help,buffer,/struct" after running this function.

HOW TO USE:

See README_Grid_Reader_IDL.txt

B.2 MATLAB-Based Data Readers

The AIRS Project releases to the broad scientific community sample data readers written in MATLAB to facilitate user community use of data products. MATLAB is an array-oriented data analysis and visualization environment developed and marketed by The MathWorks of Natick, Massachusetts.

The user community must realize that the AIRS Project does not have the resources to support consultation on these readers. They are being provided as an aid to give the user community a leg up in using the data. There is no commitment to provide assistance to the broad user community beyond the release of these readers.

B.2.1 read_L12_swath_file.m

The MATLAB procedure to read L1B and L2 Product files written in HDF-EOS swath format is provided in the file:

read_airs_swath.m

FUNCTION NAME:

read_airs_swath.m

USAGE:

buffer = read_airs_swath(filename,
content_flag,[content_list],[swathname])

INPUT ARGUMENTS:

- **filename** - The fully qualified path to a Level 1B or Level 2 HDF-EOS swath data file.
- **content_flag** - An integer that specifies the type of data to be extracted, as follows:
  - 0 - an array of the names of all data swaths in the file.
  - 1 - names and values of specified swath's dimension parameters.
  - 2 - names and values of specified swath's attribute parameters.
  - 3 - names and values of specified swath's data field parameters,
  - 4 - an array of the data field names within a specified swath.
  - **content_list** [OPTIONAL] - A cell array of text strings which are the names of specific parameters that will extracted per the content flag choice (Choices 1-3 only). If content_list is left unspecified, the function will retrieve the content on ALL items in the category specified by the content_flag.

- **swathname** [OPTIONAL] - A single text expression which is the exact name of the data swath to be extracted from the granule file. If swathname is left unspecified and there is only one data swath in a file, that swath will automatically be used.

HINT: Run this function with the content_flag=0 option first if you suspect that there are more than one data swath in a granule file. AIRS L1B and L2 Data Products have only one swath in each granule file.

OUTPUTS:

- **buffer** - This is a general-purpose data buffer. When the content_flag=0 or 4, "buffer' is a comma-delimited text string showing the names of the swaths present in the granule file. When the other content_flag options are used, buffer is a MATLAB data structure in which the results are expressed as buffer.<item_name> and buffer.<item_value>. HINT: To query these results, type "buffer" after running this function.

HOW TO USE:

See README_Swath_Reader_MATLAB.txt

B.2.2 read_airs_grid.m

The MATLAB procedure to read L3 Product files written in HDF-EOS grid format is provided in the file:

read_airs_grid.m

FUNCTION NAME:

read_airs_grid.m

USAGE:

buffer = read_airs_grid(filename, content_flag,[content_list],[gridname])

INPUT ARGUMENTS:

- **filename** - The fully qualified path to a Level 3 HDF-EOS grid data file.
- **content_flag** - An integer that specifies the type of data to be extracted, as follows:
  - 0 - an array of the names of all data grids in the file.
  - 1 - names and values of specified grid's dimension parameters.
  - 2 - names and values of specified grid's attribute parameters.
  - 3 - names and values of specified grid's data field parameters,
  - 4 - an array of the data field names within a specified grid.

- **content_list** [OPTIONAL] - A cell array of text strings which are the names of specific parameters that will extracted per the content flag choice (Choices 1-3 only). If content_list is left unspecified, the function will retrieve the content on ALL items in the category specified by the content_flag.
- **swathname** [OPTIONAL] - A single text expression which is the exact name of the data grid to be extracted from the granule file. If gridname is left unspecified and there is only one data grid in a file, that grid will automatically be used.

HINT: Run this function with the content_flag=0 option first if you suspect that there are more than one data grid in a granule file. AIRS L3 Data Products have four swaths in each granule file.

OUTPUTS:

- **buffer** - This is a general-purpose data buffer. When the content_flag=0 or 4, "buffer' is a comma-delimited text string showing the names of the grids present in the granule file. When the other content_flag options are used, buffer is a MATLAB data structure in which the results are expressed as buffer.<item_name> and buffer.<item_value>. HINT: To query these results, type "buffer" after running this function.

HOW TO USE:

See README_Grid_Reader_MATLAB.txt

B.3 FORTRAN and C Data Readers

The AIRS Project releases to the broad scientific community sample data readers written in FORTRAN and C to facilitate user community use of data products.

The user community must realize that the AIRS Project does not have the resources to support consultation on these readers. They are being provided as an aid to give the user community a leg up in using the data. There is no commitment to provide assistance to the broad user community beyond the release of these readers.

Note that AIRS products are in HDF4 format. To use the FORTRAN and C readers, the user must also download the HDF-EOS2 Library built on HDF4. This library may be accessed here:

http://www.hdfeos.org/index.php

SUMMARY OF MODULES:

See README_FORTRAN_C.txt

Examples input and output are included.

Appendix C Glossary of Acronyms

AIRS	Atmospheric InfraRed Sounder
AMSU	Advanced Microwave Sounding Unit
CLIMCAPS	Community Long-Term Infrared Microwave Combined Atmospheric Product System
CrIS	Cross-track Infrared Sounder
DAAC	Distributed Active Archive Center
DISC	Data and Information Services Center
DN	Data Number
ECMWF	European Centre for Medium Range Weather Forecasts (UK)
EOS	Earth Observing System
EOSDIS	Earth Observing System Data and Information System
EU	Engineering Unit
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
FOV	Field of View
FOR	Field of Regard
GDAAC	Goddard Space Flight Center Distributed Active Archive Center
GES	Goddard Earth Sciences
GSFC	Goddard Space Flight Center
HDF	Hierarchical Data Format
HIRAS	Hyperspectral Infrared Atmospheric Sounder
HSB	Humidity Sounder for Brazil
IASI	Infrared Atmospheric Sounding Interferometer
IR	Infrared
JPSS	Joint Polar Satellite System
L1A	Level 1A Data
L1B	Level 1B Data
L2	Level 2 Data
L3	Level 3 Data
MODIS	Moderate Resolution Imaging Spectroradiometer
MW	Microwave
NOAA	National Oceanic and Atmospheric Administration
PGE	Product Generation Executive
PGS	Product Generation System
QA	Quality Assessment
RTA	Radiative Transfer Algorithm

S-NPP	Suomi National Polar-orbiting Partnership
SPS	Science Processing System
TES	Tropospheric Emission Spectrometer
TRMM	Tropical Rainfall Measuring Mission
Vis/NIR	Visible/Near Infrared

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