JoSFRA Level-2 Products User Guide

Data products from the Joint Single Footprint Retrieval Algorithm applied to AIRS (Atmospheric Infrared Sounder) radiances

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March 2024

Document Version 2.0

Data Product Version: 02_74_01

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Pasadena, CA

Revision History

Document Version	*Software Version*	*Revision Date*	*Changes / Comments*
2.0	v02_74_01	2024-03-28	Initial Release

The research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration (80NM0018D0004).
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1.0 Introduction

This document provides basic information for using Version 2 Level-2 data products from the Joint Single Footprint Retrieval Algorithm (JoSFRA) applied to data from the Atmospheric Infrared Sounder (AIRS) instrument on the Aqua satellite. The JoSFRA algorithm approach is briefly described in Section 1.2. Users are encouraged to read the Algorithm Theoretical Basis Document for algorithm details (Irion et al., 2024).

The primary JoSFRA Level-2 retrieval products include temperature and water vapor profiles, cloud properties, and surface temperature, as well as observation metadata for six minutes of instrument observations at a time. Using single-footprint AIRS spectra results in a horizontal resolution of ~13.5 km at nadir. AIRS observations have provided near-global coverage twice daily (around 1:30 AM and PM local time) since mission launch in 2002. The initial JoSFRA data release contains a limited subset (see Section 1.8) of results from AIRS observations. JoSFRA products have been annotated with both file and variable level attributes to fully describe their contents.

1.1 Atmospheric Sounding

AIRS measures upwelling radiances in the thermal infrared as emitted from the Earth's surface, and as absorbed and emitted by atmospheric constituents. Temperature profiles are produced using measured CO_2 absorption features with varying degrees of absorption; channels with little CO_2 absorption tend to be more sensitive closer to the surface, while channels with high absorption tend to be sensitive higher in the atmosphere. Water vapor profiles use H_2O absorption features in a similar way. JoSFRA retrieves vertical profiles, also called “soundings,” by using specific sets of channels that leverage CO_2 and H_2O absorption features to create vertical profiles reported at particular pressure levels (or equivalently altitude) typically used in radiosondes.

1.2 Algorithm Background

The JoSFRA Level-2 data products are derived from observed AIRS Level 1B radiances, which are determined from raw counts obtained from the instrument’s detectors. For a definition of the NASA Data Processing Levels please see Reference 6 (NASA Processing Levels).

Technical details of the Level-2 processing steps can be found in the Algorithm Theoretical Basis Document (ATBD) [Irion et al., 2024]. Briefly, JoSFRA retrieves atmospheric and surface properties from the thermal infrared spectra at AIRS’ native horizontal footprint. Clouds are used in the forward radiative transfer model without resorting to a cloud-cleared state (as in the AIRS Version 7 or CLIMCAPS retrieval algorithms). The algorithm uses an optimal-estimation scheme (Rogers et al., 2000). Forward modeling is accomplished by using a Delta-4-Stream (D4S) parameterization for cloud transmissivities (Ou et al., 2013) incorporated into the operational AIRS forward model, the Standalone

AIRS Radiative Transfer Algorithm (SARTA; Strow et al., 2003). For a priori parameters, National Center for Environmental Prediction (NCEP) forecast products are used for temperature, skin temperature, water vapor, and surface pressure. A priori cloud-top temperature, optical depth (estimated from cloud emissivity) and daytime effective particle radius are derived from co-located Moderate Resolution Infrared Sounder (MODIS) retrievals (Platnick et al., 2017) averaged over the AIRS spatial footprint.

1.3 Suggested Use of JoSFRA

With an improved spatial resolution compared to AIRS Version 7 and CLIMCAPS-Aqua results, and with information content quantification, JoSFRA retrievals can be well-suited for process studies. Use cases for JoSFRA retrievals include instances when high spatial resolution (finer than 45 km) is needed or is beneficial, and where there are strong horizontal gradients in water vapor. Use of JoSFRA retrievals is recommended under medium to low cloud amount, or in regions above (and not below) thick clouds.

1.4 Aqua Satellite Mission

The NASA Aqua satellite, containing the AIRS instrument, was launched on May 4, 2002 into a polar sun-synchronous orbit. Orbital parameters are in Table 1.1 below. These parameters apply to most of the mission lifetime, but the orbit has now begun drifting towards later equator crossing times (see https://airs.jpl.nasa.gov/mission/instrument-operations/). Other operating instruments on board include the Advanced Microwave Sounding Unit-A (AMSU-A), the Clouds and the Earth's Radiant Energy System radiometer (CERES), the Moderate Resolution Imaging Spectroradiometer (MODIS), and the Advanced Microwave Scanning Radiometer – Earth Observing System (AMSR-E). Details about the Aqua Mission, and the AIRS instrument in particular, can be found at: https://airs.jpl.nasa.gov/.

Table 1.1 Approximate Aqua orbital parameters

Platform	Alt (km)	Orbit Incl. (°)	Equator X Time	Period (mins)	Repeat Orbits	Repeat Days	Launch
Aqua	705	98.2	13:30	98.8	233	16	04 May 2002

1.5 AIRS Instrument Description

AIRS is a hyperspectral thermal infrared grating spectrometer, with 2378 channels between 3.7 and 15.4 μm. It is a cross-track scanning instrument with a scan mirror that rotates around an axis along the line of flight and directs infrared energy emitted from the Earth into the instrument's detectors. As the spacecraft moves along, this mirror sweeps the ground creating a scan 'swath' that extends roughly 800 km on either side of the ground track. Between Earth scans, the scan mirror also allows the instrument to view various calibration sources. The scan mirror provides ±49.5° (from nadir) Earth coverage along with views to space and to on-board spectral and radiometric

calibration sources every scan cycle. The AIRS scan mirror rotates 360° every 8/3 of a second (2.667 seconds). With a solid angle width of about 1.1 degrees in diameter, the Field of View (FOV) for the AIRS instrument corresponds to a footprint of about 13.5 km in the nadir. Further details of the AIRS instrument can be found in Aumann et al. (2003).

1.6 Data Disclaimer

While every effort has been made to properly represent the data which this document describes, Version 2 JoSFRA Level-2 data are released to the public as is. Testing of the data products has been performed as described in Wong et al. (2024).

All users are encouraged to read the appropriate documentation listed in the references (Section 1.10) related to these data products to further understand the contents.

Attention should be given to quality flags, fill values and information content calculations (e.g., uncertainties or degrees-of-freedom-of-signal) before being used for any analysis or further processing of the product.

Data outages are recorded on the AIRS website, where lists of time periods are given where data were unavailable, along with short descriptions of the causes when they are known: https://airs.jpl.nasa.gov/data/outages/

1.7 Where to Find the Product

JoSFRA Level-2 products can be found at and downloaded from the NASA Goddard Earth Sciences Data and Information Services Center (GES DISC). First time users are asked to register and create an EARTHDATA login account to access the GES DISC collections. At the GES DISC website, you will find additional information and documentation about this product and other products of interest. The preferred method to locate a data collection is via the unique Digital Object Identifier (DOI) link (see Table 1.2).

The data at the GES DISC is organized by unique versioned Earth Observing System Data and Information System (EOSDIS) Core System (ECS) "ShortNames," and alternatively, users can enter the ShortName directly into the EARTHDATA search string to quickly find JoSFRA level 2 products. Also, a general search using the string "JoSFRA" under Data Collections will take to you a listing of JoSFRA products.

GES DISC website: https://disc.gsfc.nasa.gov

Table 1.2. ECS ShortName and DOI

ECS ShortName	DOI	Title
SNDRAQIL2JSFRET	10.5067/0K06YE0Y8IDS	Aqua AIRS Level 2 JoSFRA Retrieval Standard: Atmosphere cloud and surface geophysical state per footprint

1.8 Data Holdings

For the initial release of Version 2 JoSFRA, a limited test data set is provided. Future releases may expand the dataset.

The initial dataset includes:

- Full global coverage data for two 5-day periods: January 13–17, 2011; and July 13-17, 2011.
- Marine ARM GPCI Investigation of Clouds (MAGIC) Field Campaigns, 2012 – 2013 (Fig. 1.1).
- Selected granules from the years 2002 – 2007 where correlative data were available. The dots in the map in Figure 1.2 show the center of coincident AIRS granules. The locations include Dept. of Energy Atmospheric Radiation Measurement (ARM) sites at the North Slope of Alaska (NSA), Southern Great Plains (SGP), and Tropical Western Pacific (TWP), as well as scientific field campaigns.
- Granules from May to August from the years 2009 – 2019 for an 8 deg lon X 4.5 deg lat box bounded by: (32N, -92W), (36.5N, -84W).

The dataset that covers the MAGIC (Lewis, 2016) test campaign in the Pacific Ocean contains all 6-minute granules that overlap the box bounded by 20-35 degrees North latitude and 120-160 West longitude (see Figure 1.1). The time period for this data set is June 1, 2012, to September 30, 2013.

Additional JoSFRA data requests for consideration can be made at:
https://airs.jpl.nasa.gov/data/support/ask-airs

Alternatively, an email can be sent to: askairs@jpl.nasa.gov

When submitting a JoSFRA processing request for consideration, please include the following information:

- Science study, field campaign (if applicable), temporal and spatial information such as bounding box, dates (year/month/day), AIRS granule numbers (if known)

Each request will be evaluated individually due to the time and amount of resources needed to process JoSFRA.

Figure 1.1. MAGIC campaign region

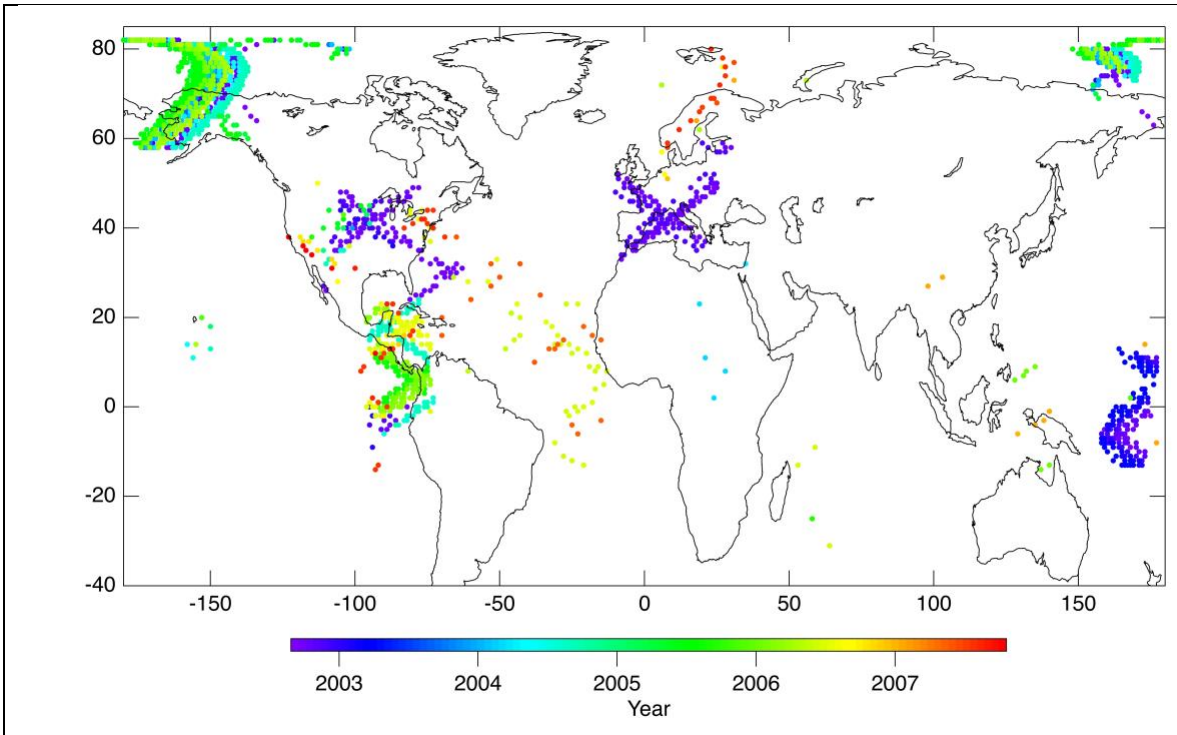

Figure 1.2. The centers of coincident AIRS granules from the years 2002-2007 where correlative data were available.

1.9 Contact Information

For information, questions or concerns with any of these JoSFRA Level-2 data sets, please submit to the AIRS Help Desk: https://airs.jpl.nasa.gov/data/support/ask-airs.

For information, questions or concerns with dataset completeness or downloading issues, please send to the GES DISC Help Desk: gsfc-dl-help-disc@mail.nasa.gov

1.10 References

All AIRS documents can be accessed through the GES DISC at the following webpage:

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

1. Irion, F. W., et al. (2024). Algorithm Theoretical Basis Document for the Joint Single Footprint Retrieval Algorithm (JoSFRA). Jet Propulsion Laboratory, California Institute of Technology.

2. Wong, S. et al. (2024). Test Report on the Joint Single Footprint Retrieval Algorithm (JoSFRA) Retrieval System for AIRS Onboard the Aqua Platform. Jet Propulsion Laboratory, California Institute of Technology.

3. Overview of the AIRS Mission: Instruments, Processing Algorithms, Products and Documentation, https://docserver.gesdisc.eosdis.nasa.gov/public/project/AIRS/Overview_of_the_AIRS_Mission.pdf

4. AIRS on-line Documentation Page: https://disc.gsfc.nasa.gov/information/documents?title=AIRS%20Documentation

5. NetCDF Climate and Forecast (CF) Metadata Conventions, Version 1.6, http://cfconventions.org/cf-conventions/v1.6.0/cf-conventions.html

6. NASA Data Processing Levels: https://earthdata.nasa.gov/collaborate/open-data-services-and-software/data-information-policy/data-levels

7. AIRS webpage, https://airs.jpl.nasa.gov

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9. Aumann, H. H., et al. (2003). AIRS/AMSU/HSB on the Aqua mission: design, science objectives, data products, and processing systems, IEEE T. Geosci. Remote, 41, 253–264.

10. Ou, S. S. C., et al. (2013). Retrieval of cirrus cloud properties from the Atmospheric Infrared Sounder: The k-coefficient approach using cloud-cleared radiances as input, IEEE T. Geosci. Remote, 51, 1010–1024.

11. Strow, L. L., et al. (2003). An overview of the AIRS radiative transfer model, IEEE T. Geosci. Remote, 41, 303–313.

12. Lewis, E.R. (2016). Marine ARM GPCI Investigation of Clouds (MAGIC) Field Campaign Report. Ed. by Robert Stafford, DOE ARM Climate Research Facility. DOE/SC-ARM-16-057. 10.2172/1343577. https://www.arm.gov/publications/programdocs/doe-sc-arm-16-057.pdf

2.0 Level-2 Product Overview

Level-2 products are created from AIRS infrared Level-1B observations using the JoSFRA algorithm.

2.1 Data Organization and Identification

The Level-2 products are divided into a series of 6-minute segments called "granules" with each granule containing 90 cross-track and 135 along-track footprints for a total of 12,150 footprints. Each file corresponds to one granule, containing all observations for a given type made during a period of exactly 6 minutes. For each day there are 240 files, identified by granule number in the filename. For example, a file name labeled with **g156** is for granule 156 out of 240. See Figure 5.1 to see how the granules for a given day map to the globe.

AIRS granules are permanently synchronized to the start of year 1956, so the actual start time of granule 1 of a given day is about five and half minutes into the day, with the exact time depending on how many leap seconds there have been. In 2002 the start time for granule 1 is T00:05:26Z, and by January 2021 it is T00:05:21Z.

The ability to uniquely identify a granule is built into the Level-1B and Level-2 products. This is extremely useful when publishing analysis results. The nominal time coverage, represented as a string: yyyymmddThhmm, is used to construct a unique granule identifier called "gran_id". gran_id is stored as a global attribute that is also used in the filename, see Section 2.4 File Naming Convention.

In addition, there is an observation identifier variable called "obs_id" that can further uniquely identify an observation within the granule. The obs_id is formatted as the gran_id with observation information appended to it. The format of AIRS obs_id is: yyyymmddThhmm.aaaExx where 'aaa' is the 3-digit along-track index (001 – 135) and xx is the cross-track index (01-90). The "E" indicates earth view.

For example:

20160125T1300.001E18

The dimensions of this variable (atrack=135, xtrack=90) correspond to the first two dimensions of the science data variables, such as temperature (air_temp). An observation ID can be associated with data by applying the same indices into these common dimensions.

2.2 File Format and Structure

The files are in Network Common Data Form, version 4 (netCDF4/HDF5) format.

The product format takes advantage of the netCDF4 data model and makes use of groups, dimensions, variables, and attributes to fully describe the science data. See Section 3.0 Data Content for a listing of key dimensions and attributes.

2.3 Metadata

Every effort has been made to ensure that metadata conforms to the Climate and Forecasting (CF), Version 1.6, and Attribute Conventions for Data Discovery (ACDD), Version 1.3, guidelines.

See the full product specifications in Appendix B.

For more information on CF, refer to: http://cfconventions.org/

For more information on ACDD, refer to:
http://wiki.esipfed.org/index.php?title=Category:Attribute_Conventions_Dataset_Discovery

2.4 File Naming Convention

File naming for Sounder SIPS products will be unique and include the following tokens separated by the delimiter '.'

<Sounder_ID>.<platform>.<inst_ID>.<gran_ID>.<product_granularity>.<granule_number>.<product_type>.<variant>.<version>.<production_location>.<prod_timestamp>.<extension>

SNDR.*platform.inst_id.yyyymmdd*T*hhmm*.m06.g101.L2_JOSFRA.std.v*mm_mm*.G.*yymmddhhmmss*.nc

Where:

- platform = AQUA
- inst_ID = AIRS
- gran_ID = Unique granule identifier yyyymmddThhmm of granule start, including year, month, day, hour, and minute of granule start time
- product_granularity = m06 (6 minute)
- granule_number = g###
  - The granule number in the day (001-240)
- product_type <product_type_name_id>
  - L2_JOSFRA
- variant = std
- version = vmm_mm - eg. v02_74_01
  - Versioning is synchronized across Sounder products
  - Aqua product versions, including v5 AIRS Level-1B
- production_location = J
  - "G" for GES DISC - Operations
  - "**J**" for production at JPL
  - "T" for a test data set

- prod_timestamp in the form yymmddhhmmss
    - This field is designed to ensure LocalGranuleIDs are unique, even when the same software is used to reprocess the same data.
- Extension (.nc)

Example Filename: 6-minute JoSFRA Level-2 granule:

SNDR.AQUA.AIRS.20160114T2359.m06.g240.L2_JOSFRA.std.v02_74_01.J.201104032757.nc

2.5 Time Representation

Times in the Level-2 products are generally represented as Coordinated Universal Time (UTC). However, observation times are provided in both UTC and TAI93 (see below) representations as a convenience to users.

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. In the data stream received from the satellite, observation times are represented as UTC.

Timestamps in product filenames and 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 (long)
20160125T1300 (compact)

The longer form is used in attributes, and the more compact form is used in filenames. The character "Z" indicates "Zulu time", or UTC.

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.

3.0 Data Content

The Level-2 data products are written in netCDF4 format and therefore make use of groups, dimensions, variables, and attributes (global & variable). Every netCDF4 file contains, at a minimum, one root group which is unnamed.

Attention should be given to quality flags and checked for fill values before being used for any analysis or further processing of the product.

A full profile of the contents of the files is included in Appendix B.

Selected fields are highlighted in this section.

3.1 Dimensions

Key dimensions for JoSFRA Level-2 products.

Table 3.1 Key Dimensions

Name	Size	Description
atrack	135	Along-track spatial dimension
xtrack	90	Cross-track spatial dimension
air_temp_pres	46	JoSFRA basis layers for air temperature retrieval
h2o_vap_pres	28	JoSFRA basis layers for water vapor retrieval

3.2 Global Attributes

There are two types of attributes: global and variable. In this section we will talk about 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, publisher and creator information, data provenance, and location information. Many attributes are required to conform to the CF & ACDD standards while other attributes are written for consistency with legacy products.

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

Table 3.2 Key Global Attributes

Name	Description
date_created	The date on which this version of the data was created
geospatial_lat_min	The southernmost latitude covered by the dataset
geospatial_lat_max	The northernmost latitude covered by the dataset

geospatial_lon_min	The westernmost longitude covered by the dataset. See also geospatial_lon_max.
geospatial_lon_max	The easternmost longitude covered by the dataset. Cases where geospatial_lon_min is greater than geospatial_lon_max indicate the bounding box extends from geospatial_lon_max, through the longitude range discontinuity at the antimeridian, to geospatial_lon_min; for example, geospatial_lon_min=170 and geospatial_lon_max=-175 incorporates 15 degrees of longitude (ranges 170 to 180 and -180 to -175).
geospatial_lat_mid	granule center latitude
geospatial_lon_mid	granule center longitude
geospatial_bounds	Describes the data's 2D or 3D geospatial extent in Open Geospatial Consortium's (OGC) Well-Known Text (WKT) Geometry format. Longitude values are limited to the (-180, 180) range. Example: 'POLYGON ((40.26 -111.29, 41.26 -111.29, 41.26 -110.29, 40.26 -110.29, 40.26 -111.29))'.
product_name_granule_number	zero-padded string for granule number of day (g001-g240)
gran_id	Unique granule identifier yyyymmddThhmm of granule start, including year, month, day, hour, and minute of granule start time
identifier_product_doi	digital object identifier (DOI); digital signature
AutomaticQualityFlag	"Passed": the granule contains a non-degraded retrieved value for at least one value in a geolocated Field-of-View (FOV); "Suspect": the granule does not qualify as "Passed" but contains a (possibly degraded) retrieved value (possibly without associated geolocation); "Failed": the granule contains no retrieved values.
qa_no_data	A simple indicator of whether this is an "empty" granule with no data from the instrument. "TRUE" or "FALSE".

3.3 Variable Attributes

Each variable has its own associated attributes. Variable attributes are a CF standard and are used to describe the variable in more detail to properly interpret its value.

Table 3.3 Variable Attributes

Attribute	Description
units	units, for variables that represent physical quantities
_FillValue	a single sentinel value indicating the data point contains fill instead of valid data
standard_name	standard name from the CF standard name table, if one exists for the quantity being represented

long_name	a longer name describing the quantity being represented, suitable for a plot title
description	a longer description of the quantity being represented
valid_range	a pair of values indicating the minimum and maximum values to be considered valid
coordinates	a space-separated list of the names of other variables that are coordinates for this variable
coverage_content_type	ACDD/ISO field categorizing types of data: • image • thematicClassification • physicalMeasurement • auxillaryInformation • coordinate • modelResult • qualityInformation • referenceInformation MD_CoverageContentTypeCode
ancillary_variables	a space-separated list of the names of other variables that contain information about this variable. These are often variables that contain error estimates.
bounds	defines the extent, for cell variables
cell_methods	describes statistical methods used to derive data, for cell variables
flag_values	These attributes collectively tell how to interpret flag variables. See the CF standard for details. In these Level-2 products, these attributes are mostly used in association with QC ancillary variables.
flag_meanings	
flag_masks	
AIRS_HDF_name	For users of AIRS retrieval products, this attribute gives the name of the most similar field in the AIRS HDF-EOS products. (Aqua)

3.4 Group Structure

One feature which was added to netCDF4 is the ability to structure files with "groups", which are similar to a directory hierarchy. SounderCDF files are designed so that all of the most commonly needed information is contained in "/", the root group. Subgroups contain more specialized information. Appendix B has a complete list of all the variables contained in each of the groups.

Table 3.4 netCDF4 Groups for retrieval files

Group	Purpose
/ (root)	Main group, with temperature and water vapor profiles, along with supporting location and quality information
/aux	A priori and supporting information primarily for the algorithm developers

3.5 Geolocation

Geolocation parameters are used for determining location of each observation on Earth and associated information about that location.

Geolocation variables are located in the file at the root level. These include latitudes and longitudes associated with each field-of-view (FOV), as well as satellite and solar geometry information, spacecraft position and orbital characteristics, surface information, and related metadata.

Table 3.5.1 Geolocation Dimensions

Dimension name	Size	Meaning
atrack	135	Along-track horizontal dimension
xtrack	90	Cross-track horizontal dimension
fov_poly	8	latitude/longitude points defining the polygon bounding an FOV (anticlockwise as viewed from above)

The key geolocation variables are:

Table 3.5.2 Key Geolocation Variables

Geolocation Variable	Dimensions	Meaning
lat	atrack, xtrack	latitude of FOV center
lon	atrack, xtrack	longitude of FOV center
lat_bnds	atrack, xtrack, fov_poly	latitude of FOV bounding polygon
lon_bnds	atrack, xtrack, fov_poly	longitude of FOV bounding polygon
land_frac	atrack, xtrack	Land fraction over the FOV
surf_alt	atrack, xtrack	mean surface altitude with respect to Earth model over FOV
obs_time_tai93	atrack, xtrack	earth view observation midtime for each fov in units of seconds since 1993-01-01T00:00:00
obs_time_utc	atrack, xtrack, utc_tuple	UTC earth view observation time as an array of integers: year, month, day, hour, minute, second, millisecond, microsecond

Full geolocation includes information about solar geometry (sol_zen, sol_azi, sun_glint_dist), viewing geometry (sat_zen, sat_azi, view_ang, sat_range, subsat_lat, …) and orbital parameters. See Appendix B for a full list of specifications.

One key feature is boundaries. Each FOV has a bounding 8-point polygon in variables {lat_bnds, lon_bnds}. This facilitates placing values in appropriate regions on a map, including the distorted shapes of FOVs at the edges of the swath.

3.6 Science Data Variables

These retrievals provide information on geophysical parameters including temperature, water vapor, and cloud properties. Many variables have associated error estimation, which is contained in variables with the same name but with "_err" appended. For example, the air temperature profile is contained in a variable named "air_temp" and its error estimate is in "air_temp_err". The "ancillary_variables" variable attribute of air_temp lists "air_temp_err". In the tables below the ancillary variables are not listed explicitly. They are indicated in the "ancillary variables" column.

Key retrieval product science data fields are defined below and are found in the /(root) group. See Appendix B for a full listing.

Table 3.6 Key JoSFRA Science Data Variables

Name	Type	Dimensions	Description	Units	Ancillary Variables
surf_temp	float32	atrack, xtrack	radiative temperature of the surface	kelvin	err
air_temp	float32	atrack, xtrack, air_temp_pres	air temperature profile on retrieval basis layers	kelvin	err
air_temp_bot_lay	float32	atrack, xtrack	air temperature of lowest full layer	kelvin	err
spec_hum	float32	atrack, xtrack, h2o_vap_pres	mass fraction of water vapor in moist air	kg / kg	err
spec_hum_bot_lay	float32	atrack, xtrack	mass fraction of water vapor in moist air of lowest full layer	kg / kg	err
rel_hum	float32	atrack, xtrack, h2o_vap_pres	relative humidity over equilibrium phase	unitless	err
rel_hum_bot_lay	float32	atrack, xtrack	relative humidity near the surface over equilibrium phase	unitless	err
cld_top_temp	float32	atrack, xtrack	cloud top temperature	kelvin	err
cld_top_pres	float32	atrack, xtrack	cloud top pressure	Pa	err, num_cld
cld_optical_depth	float32	atrack, xtrack	cloud optical depth	unitless	err
cld_eff_radius	float32	atrack, xtrack	cloud particle effective radius	m	err

Note that JoSFRA products include retrieved values for ozone and carbon dioxide, but these gasses are only retrieved as interferants or to improve temperature retrievals. Retrieved amounts of ozone and carbon dioxide are not recommended for use in further studies (see Irion et al., 2024).

3.7 Quality Information

For most retrieved geophysical variables, a numerical error estimate in the same physical units is provided in a corresponding ancillary_variable with a name ending in "_err".

The overall quality of retrieval is indicated Quality Control (QC) scores of {0, 1, 2, 3} in "qc_flag_step_one" and "qc_flag_step_two".

Table: 3.7 Quality Control qc_flag_step_* Values

QC Value	Meaning
0	Good quality from top-of-atmosphere to surface
1	Good quality from top-of-atmosphere to a certain pressure level, qc_pres or qc_pres_h2o_vap (see text)
2	Do not use. In some cases, a physical value is present but is not considered reliable. In other cases, only fill values are present.
3	Retrieval failure

The most straightforward way to use the QC values is to look only at the variables qc_pres_h2o_vap (for water vapor) and qc_pres (for everything else). For pressure layers from the top of the atmosphere down to this pressure level (in Pa) the quality is considered good; below this level it is considered unreliable.

As noted in section 3.11.1, there are some ocean retrievals where the quality of the surface and cloud fields is poorer than indicated by qc_flag_step_* and qc_pres. Do not use these fields for ocean cases where |surf_temp – aux/fg_surf_temp| > 5.0:

1) surf_temp
2) surf_ir_emis
3) cld_top_temp
4) cld_top_pres
5) cld_optical_depth
6) cld_eff_radius

The JoSFRA retrieval is performed in two steps. In "Step One," simultaneous retrieval of the temperature and CO_2 profiles, surface temperature, cloud properties and emissivity (over land) is performed, mostly using channels in the 14 μm CO_2 band and window regions, with ozone and water vapor also retrieved as "interferent" gases. In "Step Two," retrievals from Step One are used as fixed parameters, except that the water vapor profile a priori reverts

back to the NCEP forecast. The channel selection is modified to concentrate on water absorption channels between 768 and 1605 cm^{-1}, and only the water vapor profile is retrieved.

There are separate quality control flags for Step One retrievals and Step Two retrievals (water vapor): qc_flag_step_one and qc_flag_step_two. Flags are 0 (good from top-of-atmosphere to surface), 1 (good from top-of-atmosphere to qc_pres, described below), 2 (do not use), and 3 (retrieval failure). We describe the criteria for these in reverse order.

QC = 3 (retrieval failure)

Retrievals that encounter an unrecoverable error in the solver (e.g., attempted inversion of a singular matrix) or elsewhere in the algorithm are given a QC flag = 3 (retrieval failure). No retrieval results or a priori data are written out, although future versions of JoSFRA will write out a priori data.

QC = 2 (do not use)

Retrievals with either or both of the following are output with QC = 2 (Do Not Use):

1. Normal convergence is not obtained within the maximum specified number of iterations (currently 60), or

2. Chi square fitting parameter, $\chi^2 > 3$.

The first criterion is to avoid waste of computational resources on poorly- or non-converging retrievals. The second criterion is to avoid reporting profiles with poor spectral fits. Discussion of the chi square fitting parameter can be found in Section 2.7.3 of the JoSFRA ATBD [Irion et al., 2024].

For the user who would prefer to use their own χ^2 criterion in analyzing JoSFRA output, note that the retrieval χ^2's are given in "chi2_step_one" and "chi2_step_two" in the output. Retrievals that converge (regardless of the χ^2) will have "/aux/stop_code_step_one" and/or "/aux/stop_code_step_two" equal to 1. Retrievals that reach the maximum allowable number of iterations will have "/aux/stop_code_step_one" and/or "/aux/stop_code_step_two" equal to 2.

QC = 1 (good from top-of-atmosphere to qc_pres)

This QC flag indicates when retrieval profiles are considered good to just above the cloud-top, but are not reliable below. To summarize, retrievals in layers with $T_{atm} > (T_{cldtop} - 10$ K), where T_{cldtop} is cloud-top temperature, require a surface temperature averaging kernel > 0.6; qc_pres is calculated where $T_{atm} = T_{cldtop} - 10$ K. The averaging kernel referred to in the criterion is a matrix which is a measure of the sensitivity of each retrieved variable to changes in the true state of the atmosphere.

QC = 0 (good from top-of-atmosphere to surface)

If a retrieval (a) converges within the specified maximum number of iterations, (b) has a retrieval $\chi^2 \leq 3$, and (c) has a surface temperature averaging kernel > 0.6, then the retrieval is considered "good" from top-of-atmosphere to the surface. (In this case, qc_pres is reported as the surface pressure).

Note that it is possible that if the Step One QC flag is 0 or 1, the Step Two QC flag can be 2 (non-convergence or $\chi^2 > 3$) or 3 (retrieval failure). This can happen if the Step Two water vapor retrieval is unsuccessful after a successful Step One retrieval. Note that the qc_pres determined in Step One is also used for the Step Two H_2O retrieval profile.

In addition to the QC variables discussed above, there are other indicators of quality. Error estimations are given for retrieved quantities. Degrees-of-freedom-of-signal (DOFS) are also given for individual quantities (air_temp_dof, h2o_vap_dof, etc.). Generally, the higher the DOFS, the more the retrieval for a constituent is based on the spectra as opposed to the a priori.

3.8 Missing Data / Fill Values

Fill values are used where there is no valid data, including profiles level with pressures greater than the surface pressure. The fill value is indicated by the attribute '_FillValue'. It is advised to check the data for fill values before it is used. The fill values per variable datatype are listed in the table below.

Table: 3.8 Fill Values

Variable Type	Fill Value
unsigned 8-bit integer	255UB
unsigned 16-bit integer	65535US
unsigned 32-bit integer	4294967295U
floating point	9.96921e+36

3.9 Key Supporting Information Variables for Profiles

These variables provide supporting information to interpret the science variables.

Name	Dimensions	Description	Units
air_temp_pres	air_temp_pres	Static pressures of layers used in the retrieval of the air temperature profile.	Pa
air_temp_pres_bnds	air_temp_pres, bnds_1d	Min and max pressure of each air temperature layer	Pa
h2o_vap_pres	h2o_vap_pres	Static mid-layer pressures of layers used in the retrieval of the water vapor profile.	Pa
h2o_vap_pres_bnds	h2o_vap_pres, bnds_1d	Min and max pressure of each water vapor layer	Pa

3.10 Vertical Profile Representation of Gases

JoSFRA retrieves all species as vertical profiles on different subsets of the 100 fixed-pressure layers used to satisfy internal requirements for radiative transfer calculations. For each species there is one variable giving the mid-layer pressure, like "air_temp_pres", and another with the top and bottom pressure levels of that layer, like "air_temp_pres_bnds". Separate variables, like "air_temp_bot_lay", store information on the lowest full layer above the surface.

Pressure layers below the surface are always filled with fill values.

3.11 Known Issues

More details for some of the issues below can be found in the JoSFRA test report, Wong et al. (2024), along with further comparisons and testing results.

3.11.1 Ocean Surface Temperature

Retrievals of ocean surface temperature can often significantly deviate from the a priori (> ±5K). The ocean surface temperature a priori “aux/fg_surf_temp”, although from a forecast, is considered reasonably reliable given the low diurnal and day-to-day variations expected.

Figure 3.1 shows the JoSFRA surface skin temperature compared to it’s a priori for a single example date (January 13, 2011). The significant differences (> ±5 K, red or blue dots), although not common, are evident over both ocean and land. Over land, however, both satellite retrievals and models are more challenged due to complex topography and variability, so deviations from the a priori are not as useful as indicators of problematic retrievals. Further comparisons of surface temperature retrievals to their a priori and analysis of impacts of the surface temperature are contained in an appendix to the JoSFRA test report (Wong et al., 2024).

The ocean temperature bias is often correlated with cloud-top temperature biases and/or (visible) cloud optical depth biases from the MODIS-derived a priori. Biases in the retrieved profiles of temperature and water vapor were much less correlated with biases in ocean skin temperature. Since cloud property retrieval and ocean surface temperature retrieval rely more strongly on “window channels,” while profile retrievals rely on spectral lines, bias errors in the cloud retrieval cause more bias error in the ocean surface temperature than profiles.

Both the a priori and retrieved values of ocean surface temperature (“aux/fg_surf_temp” and “surf_temp”), cloud-top temperature (“aux/fg_cld_top_temp” and “cld_top_temp”), and cloud optical depth (“aux/fg_cld_optical_depth” and “cld_optical_depth”) are given for each footprint. In areas where the retrieved ocean skin temperature is significantly different from the a priori (|surf_temp – aux/fg_surf_temp| > 5.0), users may find it advantageous to instead use the forecast skin temperature and the (MODIS-derived) cloud-top temperature and (visible) cloud optical depth (see suggestion in Section 3.7).

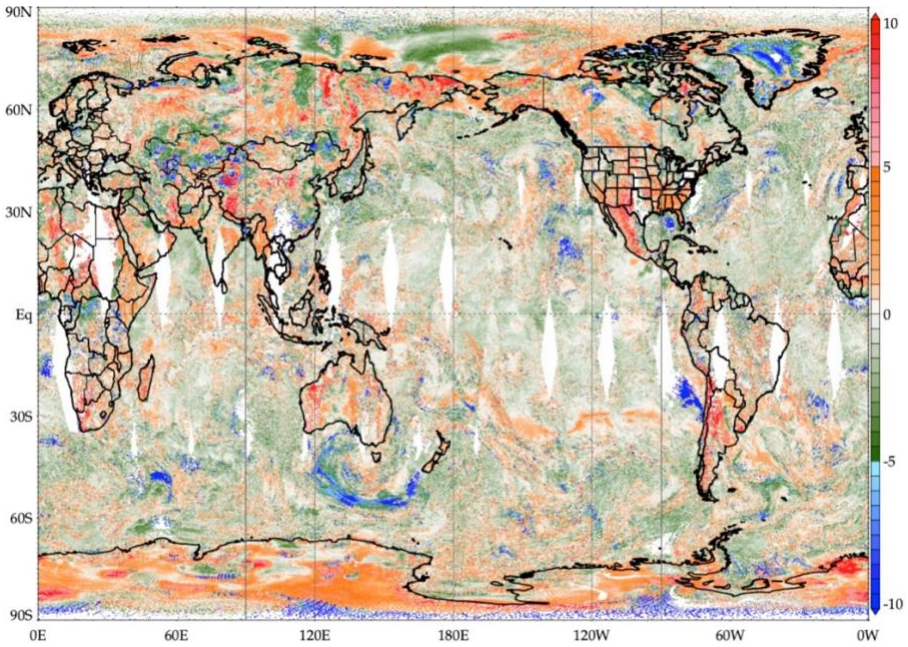


Figure 3.1 JoSFRA surface skin temperature compared to it's a priori from NCEP forecasts for one test date (January 13, 2011).

We again note that the a priori (visible) cloud optical depth is derived from the MODIS cloud emissivity. Emissivity is used to derive optical depth since optical depth is reported daytime only for MODIS while emissivity is reported day-and-night. Since the maximum MODIS emissivity reported is 0.99, the optical depth a priori has maximum of 9.21.

3.11.2 Temperature and Humidity Profiles

JoSFRA can have low yield for temperature and specific humidity due to the existence of thick clouds, especially over the tropical Western Pacific, where over 80% of the retrievals were flagged as not suitable for scientific use (QC=2).

When compared to IGRA radiosondes, JoSFRA temperature retrievals have a large warm bias during daytime January cases in the tropics. And JoSFRA specific humidity retrievals tend to have a much moister tropical and mid-latitude troposphere at 500-800 hPa. Also, JoSFRA specific humidity retrievals have random sudden spikes in RMSEs in the vertical profiles. The origin of these discontinuous jumps is not clear.

3.11.3 Cloud Top Properties

Reported cloud top pressures sometimes place clouds below the surface.

Cases where the a priori cloud-top temperature was assumed may have over-constrained results, and likely have output errors that are significantly underestimated. These cases have the output field "/aux/cld_top_temp_fg_src" marked as "2" (assumed) or "3" (Cld T assumed for cirrus). The cloud-top temperature was assumed (a) where estimating the

MODIS cloud-top temperature failed, and (b) the scene was not determined to be clear by other tests (see Irion, ATBD). In these cases, the a priori covariance for MODIS-derived cloud-top temperature ((4K)^2) was erroneously used when a covariance of (25K)^2 should instead have been used. The resulting cloud-top temperature retrieval may thus be overly close to the first guess and is likely to have an underestimated error. However, such cases tend to occur under very low cloud opacity and are not expected to significantly affect retrievals of other parameters.

Testing of cloud results revealed that some retrieved cloud-top temperatures (CTT) and cloud-top pressures are questionably high. Approximately 1% of retrievals for July 13-17, 2011 had a CTT >= 300K. Some of these can be attributed to a high MODIS-derived a priori CTT — 0.3% of a priori values were >= 300K. For other high values, we hypothesize that in the Levenberg-Marquardt minimization algorithm (see Irion et al., 2024), overly high cloud-top temperatures can be tested that "put" the cloud below ground in the forward model — effectively removing the cloud from the radiance modeling, but not the state vector. If an iteration results in a lowered cost function, an overly-high CTT can thus be reported in the output. We note that for extreme cases (> 320K), the cloud-top temperature degrees-of-freedom-of-signal (DOFS) is usually zero, and the cloud optical depth DOFS is almost always zero, indicating little-to-no information about the cloud state is gleaned from the spectrum. Users are advised to check the fields cld_top_temp_dof and cld_optical_depth_dof when using JoSFRA cloud-top temperature in research. More investigation is needed, however, future versions of JoSFRA are expected to have the cloud-top temperature better constrained and/or formulated differently within the retrieval so these erroneous results can be avoided.

3.11.4 Trace Gases

Ozone (O_3) and carbon dioxide (CO_2) are only retrieved to aid in retrieval of temperature and water vapor. While O_3 and CO_2 are reported in the product files, their use is not recommended for further study.

Incorrect pressures were used internally for calculation of the total ozone column, and the reported total ozone column is therefore also incorrect.

4.0 Options for Reading the Data

The product files are written in netCDF4/HDF5. Because netCDF4 builds upon the classic netCDF data model using HDF5 as the storage layer, a user of the data product can take full advantage of tools and libraries readily available to access the data.

Every netCDF4 file is considered an HDF5 file, however, not every HDF5 file is necessarily a netCDF4 file. A limited subset of the HDF5 data model and file format features are used in netCDF4 files. Conformance to the earlier mentioned CF & ACDD standards allows for users to take advantage of most netCDF interfaces.

Tools and libraries for reading netCDF4 as well as a netCDF Users' Guide are written and maintained by Unidata and can be found online at:
http://www.unidata.ucar.edu/software/netcdf/

Panoply is a good netCDF data viewer tool for visualizing these files.
https://www.giss.nasa.gov/tools/panoply/

There are a number of interfaces available for reading netCDF for different programming languages including: C/C++, Fortran, Matlab, IDL, Python and Perl.

The files can also be accessed with HDF5 tools and libraries available at:
https://www.hdfgroup.org/products/hdf5_tools/

5.0 Data Services

The products are available to the user community via the GES DISC:
https://disc.gsfc.nasa.gov/

In addition to the netCDF data files, there you can also get daily granule maps, showing the location of each granule of each day.

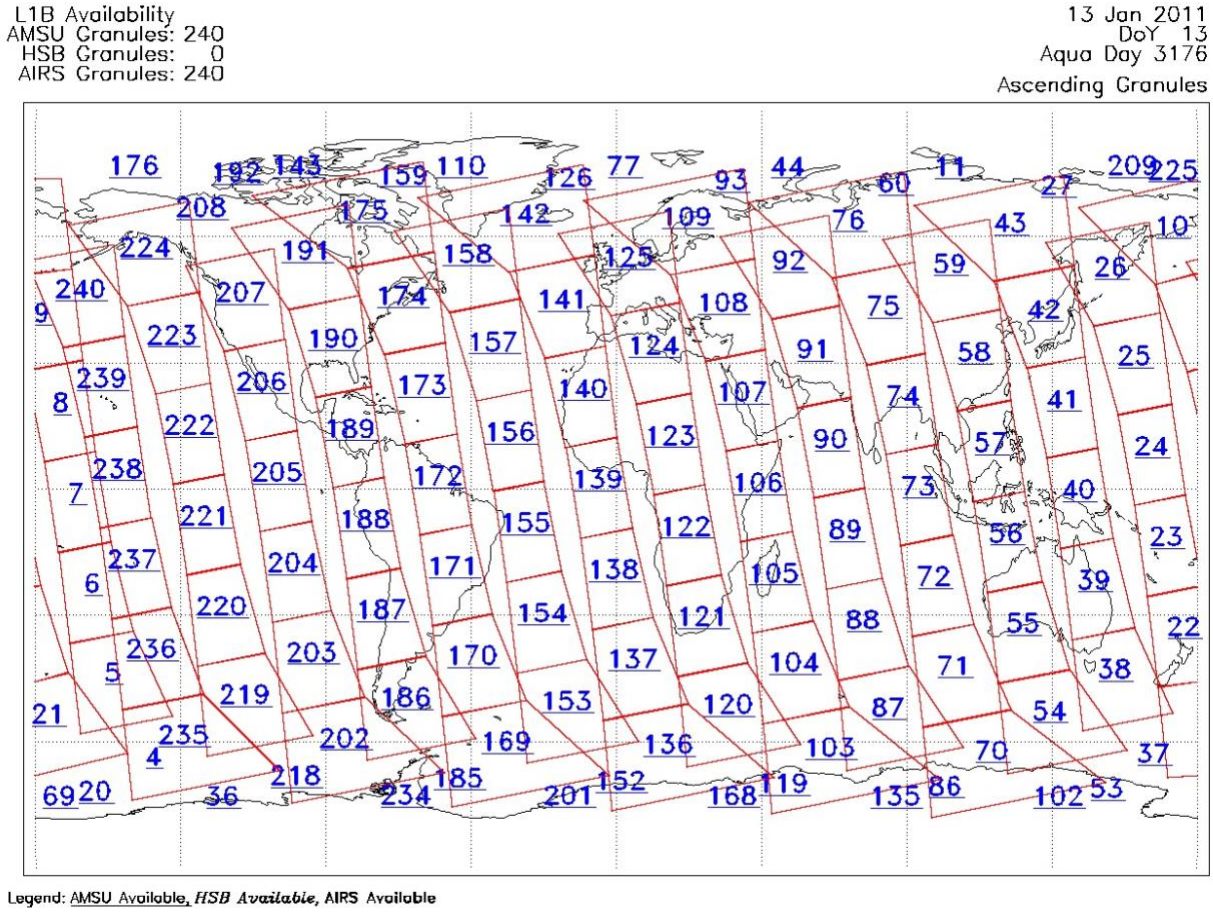
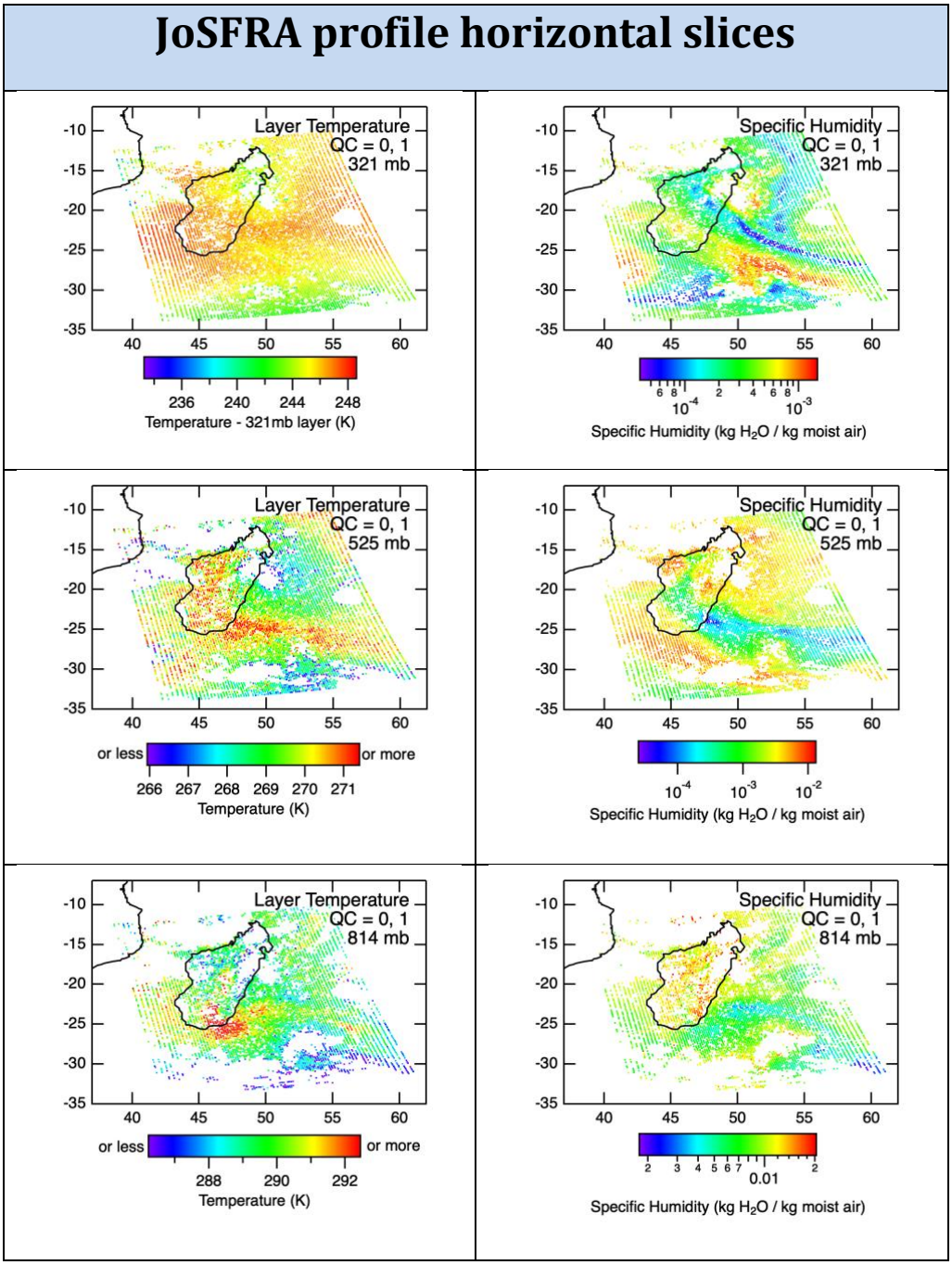


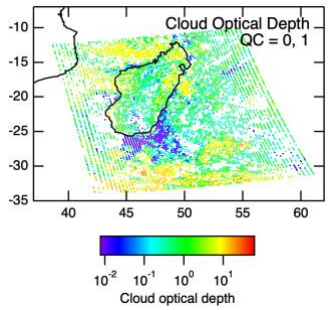
Figure 5.2. AIRS Granule map for Daytime data 2011-01-13. Granule 105 from this date is used in Appendix A.

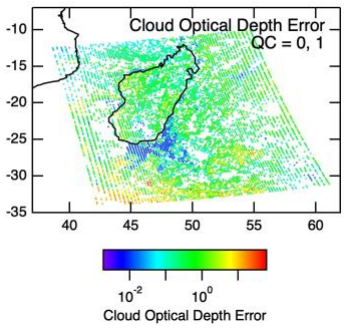
Appendix A: Sample Images

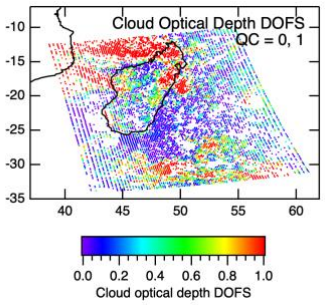
These images of JoSFRA retrieval results for 2011-01-13 granule 105 (gran_id = 20110113T1029) were generated with IGOR. This granule covers Madagascar and the surrounding area of the Indian Ocean during the day.

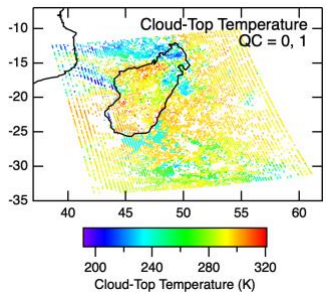


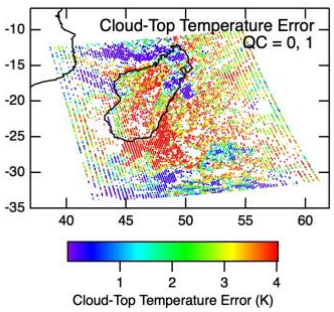
JoSFRA clouds

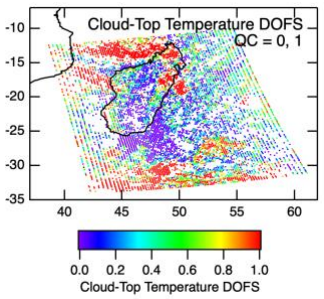


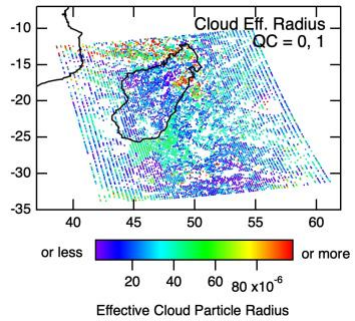


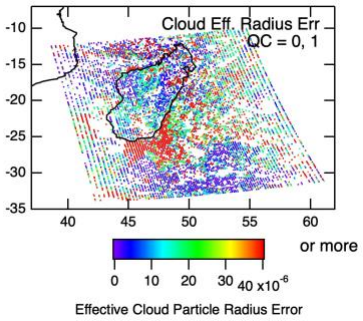


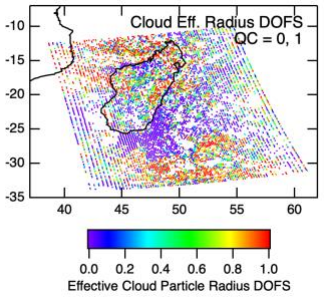




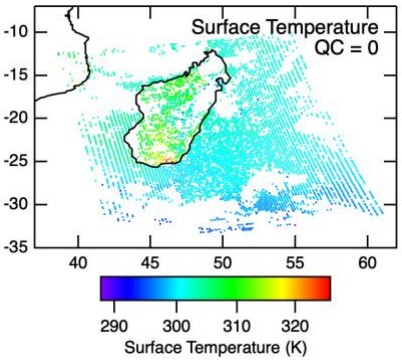


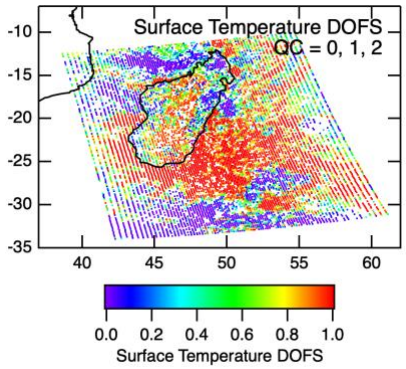






JoSFRA surface





Appendix B: Detailed File Format

The tables in this appendix list all the dimensions, global attributes, and variables in product files for the JoSFRA Level-2 product.

For clarity, some variable attributes are omitted, including long_name, standard_name, coverage_content_type, axis, valid_range, coordinates, AIRS_HDF_name, and _FillValue.

Ancillary variables are also omitted. The presence of “bnds” in the ancillary_variables column for “lat” means that there is also a variable named “lat_bnds”.

To get a complete listing including all variable attributes and the actual values contained in the header, apply “ncdump -h <filename>” to any netCDF4 product file.

L2 JoSFRA AIRS IR Interface Specification

Interface Specification Version v02.02.59
08-09-2023

Groups

Path	Description
/	Main science data
/aux	Internal product team data

Global Dimensions

Name	Size	Description
utc_tuple	8	parts of UTC time: year, month, day, hour, minute, second, millisec, microsec
atrack	135	along-track horizontal dimension
xtrack	90	cross-track horizontal dimension
surf_wnum_ir	10	IR surface emissivity hinge points
air_temp_pres	46	JoSFRA basis layers for air temperature retrieval
h2o_vap_pres	28	JoSFRA basis layers for water vapor retrieval
o3_pres	18	JoSFRA basis layers for ozone retrieval
co2_pres	10	JoSFRA basis layers for carbon dioxide retrieval
bnds_1d	2	Boundaries for 1-D fields like pressure layers: min, max
fov_poly	8	lat_bnds, lon_bnds points defining the polygon bounding an FOV (anticlockwise as viewed from above)
spatial	3	directions: x, y, z for satellite position and velocity

Name	Size	Description
attitude	3	roll, pitch, yaw

Global Variables

Name	Type	Dimensions	Description	Units	Ancillary Variables
obs_id	string	atrack, xtrack	unique earth view observation identifier: yyyymmddThhmm.aa[a]Exx . Includes gran_id plus two- or three-digit along-track index (01-45 or 001-135) and 2-digit cross-track index (01-96).		
obs_time_tai93	double	atrack, xtrack	TAI93 earth view observation midtime for each FOV in seconds since 1993-01-01 00:00z	seconds since 1993-01-01 00:00	
obs_time_utc	uint16	atrack, xtrack, utc_tuple	UTC earth view observation midtime for each FOV as an array of integers: year, month, day, hour, minute, second, millisec, microsec		
lat	float	atrack, xtrack	latitude of FOV center	degrees_north	bnds
lat_geoid	float	atrack, xtrack	latitude of FOV center on the geoid (without terrain correction)	degrees_north	
lon	float	atrack, xtrack	longitude of FOV center	degrees_east	bnds
lon_geoid	float	atrack, xtrack	longitude of FOV center on the geoid (without terrain correction)	degrees_east	
land_frac	float	atrack, xtrack	land fraction over the FOV	unitless	
surf_alt	float	atrack, xtrack	mean surface altitude wrt earth model over the FOV	m	sdev
sun_glint_lat	float	atrack	sun glint spot latitude at scan_mid_time. Fill for night observations.	degrees_north	
sun_glint_lon	float	atrack	sun glint spot longitude at scan_mid_time. Fill for night observations.	degrees_east	
sol_zen	float	atrack, xtrack	solar zenith angle at the center of the spot	degree	
sol_azi	float	atrack, xtrack	solar azimuth angle at the center of the spot (clockwise from North)	degree	

Name	Type	Dimensions	Description	Units	Ancillary Variables
sun_glint_dist	float	atrack, xtrack	Distance from the center of the calculated sun glint spot to the center of the spot. Note that there may not be a glint for cloudy or land cases and in ocean cases the glint can move based on wind conditions. Fill for night observations.	m	
view_ang	float	atrack, xtrack	off nadir pointing angle	degree	
sat_zen	float	atrack, xtrack	satellite zenith angle at the center of the spot	degree	
sat_azi	float	atrack, xtrack	satellite azimuth angle at the center of the spot (clockwise from North)	degree	
sat_range	float	atrack, xtrack	line of sight distance between satellite and spot center	m	
asc_flag	ubyte	atrack	ascending orbit flag: 1 if ascending, 0 descending		
subsat_lat	float	atrack	sub-satellite latitude at scan_mid_time	degrees_north	
subsat_lon	float	atrack	sub-satellite longitude at scan_mid_time	degrees_east	
scan_mid_time	double	atrack	TAI93 at middle of earth scene scans	seconds since 1993-01-01 00:00	
sat_alt	float	atrack	satellite altitude with respect to earth model at scan_mid_time	m	
sat_pos	float	atrack, spatial	satellite ECR position at scan_mid_time	m	
sat_vel	float	atrack, spatial	satellite ECR velocity at scan_mid_time	m s-1	
sat_att	float	atrack, attitude	satellite attitude at scan_mid_time. An orthogonal triad. First element is angle about the +x (roll) ORB axis. +x axis is positively oriented in the direction of orbital flight. Second element is 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. Third element is 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.	degree	
local_solar_time	float	atrack, xtrack	local apparent solar time in hours from midnight	hours	
mean_anom_wrt_equat	float	atrack	spacecraft mean anomaly measured with respect to the ascending node	degree	

Name	Type	Dimensions	Description	Units	Ancillary Variables
sat_sol_zen	float	atrack	solar zenith angle at the satellite	degree	
sat_sol_azi	float	atrack	solar azimuth angle at the satellite (clockwise from North)	degree	
asc_node_lon	float		Longitude of the last ascending node of spacecraft orbit before time_coverage_end.	degrees_east	
asc_node_tai93	double		TAI93 time of the last ascending node of spacecraft orbit before time_coverage_end.	seconds since 1993-01-01 00:00	
asc_node_local_solar_time	float		local apparent solar time at the last ascending node before time_coverage_end in hours from midnight	hours	
solar_beta_angle	float		Beta angle for the spacecraft orbit, determining the percentage of the orbit that the spacecraft is in direct sunlight.	degree	
attitude_lbl	string	attitude	list of rotational directions (roll, pitch, yaw)		
spatial_lbl	string	spatial	list of spatial directions (X, Y, Z)		
utc_tuple_lbl	string	utc_tuple	names of the elements of UTC when it is expressed as an array of integers year,month,day,hour,minute,second,millisecond,microsecond		
air_temp_dof	float32	atrack, xtrack	The trace of the averaging kernel matrix as a measure of the amount of information about the air temperature profile extracted from the measured radiation.	unitless	
h2o_vap_dof	float32	atrack, xtrack	The trace of the averaging kernel matrix as a measure of the amount of information about the water vapor profile extracted from the measured radiation.	unitless	
o3_tot	float32	atrack, xtrack	Total column ozone. (Multiply by 4.670e4 to convert to Dobson Units from kg m^-2)	kg m-2	err
o3_dof	float32	atrack, xtrack	The trace of the averaging kernel matrix as a measure of the amount of information about the ozone profile extracted from the measured radiation.	unitless	

Name	Type	Dimensions	Description	Units	Ancillary Variables
co2_dof	float32	atrack, xtrack	The trace of the averaging kernel matrix as a measure of the amount of information about the carbon dioxide profile extracted from the measured radiation.	unitless	
surf_temp	float32	atrack, xtrack	radiative temperature of the surface	kelvin	err
surf_temp_dof	float32	atrack, xtrack	The trace of the averaging kernel matrix as a measure of the amount of information about the surface temperature extracted from the measured radiation.	unitless	
surf_ir_emis_dof	float32	atrack, xtrack	The trace of the averaging kernel matrix as a measure of the amount of information about the surface IR emissivity extracted from the measured radiation.	unitless	
surf_ir_emis	float32	atrack, xtrack, surf_wnum_ir	Infrared surface emissivity	unitless	err
surf_wnum_ir	float32	surf_wnum_ir	Surface infrared emissivity frequencies (hinge points)	cm-1	
air_temp_pres	float32	air_temp_pres	Static pressures of layers used in the retrieval of the air temperature profile.	Pa	lay_bnds
air_temp	float32	atrack, xtrack, air_temp_pres	air temperature profile on retrieval basis layers	kelvin	err
air_temp_bot_lay	float32	atrack, xtrack	air temperature of lowest full layer	kelvin	err
h2o_vap_pres	float32	h2o_vap_pres	Static mid-layer pressures of layers used in the retrieval of the water vapor profile.	Pa	lay_bnds
spec_hum	float32	atrack, xtrack, h2o_vap_pres	mass fraction of water vapor in moist air	kg / kg	err
spec_hum_bot_lay	float32	atrack, xtrack	mass fraction of water vapor in moist air of lowest full layer	kg / kg	err
rel_hum	float32	atrack, xtrack, h2o_vap_pres	relative humidity over equilibrium phase	unitless	err
rel_hum_bot_lay	float32	atrack, xtrack	relative humidity near the surface over equilibrium phase	unitless	err

Name	Type	Dimensions	Description	Units	Ancillary Variables
o3_pres	float32	o3_pres	Static mid-layer pressures of layers used in the retrieval of the ozone profile.	Pa	lay_bnds
o3_vmr	float32	atrack, xtrack, o3_pres	ozone VMR	unitless	err
o3_vmr_bot_lay	float32	atrack, xtrack	ozone VMR of lowest full layer	unitless	err
co2_pres	float32	co2_pres	Static pressures of layers used in the retrieval of the carbon dioxide profile.	Pa	lay_bnds
co2_vmr	float32	atrack, xtrack, co2_pres	carbon dioxide VMR	m3 / m3	err
co2_vmr_bot_lay	float32	atrack, xtrack	carbon dioxide VMR of lowest full layer	m3 / m3	err
chi2_step_one	float32	atrack, xtrack	Chi squared for the retrieval spectral fit, step one: everything except water vapor	unitless	
chi2_step_two	float32	atrack, xtrack	Chi squared for the retrieval spectral fit, step two: water vapor	unitless	
qc_flag_step_one	byte	atrack, xtrack	QC Flag (step one -- everything but water vapor): 0 == passed QC to surface; 1 == use retrieved quantities other than water vapor with caution at pressures at or greater than qc_pres; 2 == do not use; 3 == retrieval failure		
qc_flag_step_two	byte	atrack, xtrack	QC Flag (step two -- water vapor): 0 == water vapor passed QC to surface; 1 == use retrieved water vapor with caution at pressures at or greater than qc_pres_h2o_vap; 2 == do not use water vapor; 3 == water vapor retrieval failure		
qc_pres	float32	atrack, xtrack	QC pressure threshold: Retrieved quantities other than water vapor at layer pressures at or higher than qc_pres should be used with caution.	Pa	
qc_pres_h2o_vap	float32	atrack, xtrack	QC pressure threshold: Retrieved water vapor at layer pressures at or higher than qc_pres should be used with caution.	Pa	
cld_top_temp	float32	atrack, xtrack	cloud top temperature	kelvin	err
cld_top_temp_dof	float32	atrack, xtrack	An element of the averaging kernel matrix as a measure of the amount of information about the cloud top temperature provided by the physical retrieval.	unitless	

Name	Type	Dimensions	Description	Units	Ancillary Variables
cld_top_pres	float32	atrack, xtrack	cloud top pressure	Pa	err, num_cld
cld_optical_depth	float32	atrack, xtrack	cloud optical depth	unitless	err
cld_optical_depth_dof	float32	atrack, xtrack	An element of the averaging kernel matrix as a measure of the amount of information about the cloud optical depth provided by the physical retrieval.	unitless	
cld_eff_radius	float32	atrack, xtrack	cloud particle effective radius	m	err
cld_eff_radius_dof	float32	atrack, xtrack	An element of the averaging kernel matrix as a measure of the amount of information about the cloud particle effective radius provided by the physical retrieval.	unitless	
cld_rad_wlen	float32		wavelength for cloud optical depth	m	

Global Attributes

Name	Type	Size	Value	Description
Format	string	1	netCDF	Format of the data, e.g., HDF-EOS5 or netCDF.
Conventions	string	1	CF-1.6, ACDD-1.3	A comma-separated list of the conventions that are followed by the dataset.
history	string	1		Provides an audit trail for modifications to the original data. This attribute is also in the NetCDF Users Guide: 'This is a character array with a line for each invocation of a program that has modified the dataset. Well-behaved generic netCDF applications should append a line containing: date, time of day, user name, program name and command arguments.' To include a more complete description you can append a reference to an ISO Lineage entity; see NOAA EDM ISO Lineage guidance.
source	string	1	AIRS instrument telemetry	The method of production of the original data. If it was model-generated, source should name the model and its version. If it is observational, source should characterize it. This attribute is

Name	Type	Size	Value	Description
				defined in the CF Conventions. Examples: 'temperature from CTD #1234'; 'world model v.0.1'.
processing_level	string	1	2	A textual description of the processing (or quality control) level of the data.
product_name_type_id	string	1	L2_JOSFRA	Product name as it appears in product_name (L1A, L1B, L2, SNO_AIRS_CrIS)
comment	string	1		Miscellaneous information about the data or methods used to produce it. Can be empty.
acknowledgment	string	1	Support for this research was provided by NASA.	A place to acknowledge various types of support for the project that produced this data.
license	string	1	Unassigned	Provide the URL to a standard or specific license, enter "Freely Distributed" or "None", or describe any restrictions to data access and distribution in free text.
standard_name_vocabulary	string	1	CF Standard Name Table v28	The name and version of the controlled vocabulary from which variable standard names are taken. (Values for any standard_name attribute must come from the CF Standard Names vocabulary for the data file or product to comply with CF.) Example: 'CF Standard Name Table v27'.
date_created	string	1	Unassigned	The date on which this version of the data was created. (Modification of values implies a new version, hence this would be assigned the date of the most recent values modification.) Metadata changes are not considered when assigning the date_created. The ISO 8601:2004 extended date format is recommended, as described in the Attribute Content Guidance section.
creator_name	string	1	Unassigned	The name of the person (or other creator type specified by the creator_type attribute) principally responsible for creating this data.
creator_email	string	1	Unassigned	The email address of the person (or other creator type specified by the creator_type attribute) principally responsible for creating this data.

Name	Type	Size	Value	Description
creator_url	string	1	Unassigned	The URL of the person (or other creator type specified by the creator_type attribute) principally responsible for creating this data.
institution	string	1	Unassigned	Processing facility that produced this file
project	string	1	AIRS	The name of the project(s) principally responsible for originating this data. Multiple projects can be separated by commas, as described under Attribute Content Guidelines. Examples: 'PATMOS-X', 'Extended Continental Shelf Project'.
product_name_project	string	1	AIRS	
publisher_name	string	1	Unassigned	The name of the person (or other entity specified by the publisher_type attribute) responsible for publishing the data file or product to users, with its current metadata and format.
publisher_email	string	1	Unassigned	The email address of the person (or other entity specified by the publisher_type attribute) responsible for publishing the data file or product to users, with its current metadata and format.
publisher_url	string	1	Unassigned	The URL of the person (or other entity specified by the publisher_type attribute) responsible for publishing the data file or product to users, with its current metadata and format.
geospatial_bounds	string	1		Describes the data's 2D or 3D geospatial extent in OGC's Well-Known Text (WKT) Geometry format (reference the OGC Simple Feature Access (SFA) specification). The meaning and order of values for each point's coordinates depends on the coordinate reference system (CRS). The ACDD default is 2D geometry in the EPSG:4326 coordinate reference system. The default may be overridden with geospatial_bounds_crs and geospatial_bounds_vertical_crs (see those attributes). EPSG:4326 coordinate values are longitude (decimal degrees_east) and latitude (decimal degrees_north), in that order. Longitude values in the default case are limited to the [-180, 180) range. Example: 'POLYGON ((-111.29 40.26, -111.29 41.26, -110.29 41.26, -110.29 40.26, -111.29 40.26))'.

Name	Type	Size	Value	Description
geospatial_bounds_crs	string	1	EPSG:4326	The coordinate reference system (CRS) of the point coordinates in the geospatial_bounds attribute. This CRS may be 2-dimensional or 3-dimensional, but together with geospatial_bounds_vertical_crs, if that attribute is supplied, must match the dimensionality, order, and meaning of point coordinate values in the geospatial_bounds attribute. If geospatial_bounds_vertical_crs is also present then this attribute must only specify a 2D CRS. EPSG CRSs are strongly recommended. If this attribute is not specified, the CRS is assumed to be EPSG:4326. Examples: 'EPSG:4979' (the 3D WGS84 CRS), 'EPSG:4047'.
geospatial_lat_min	float	1	9.9692099683868690e+36f	Describes a simple lower latitude limit; may be part of a 2- or 3-dimensional bounding region. Geospatial_lat_min specifies the southernmost latitude covered by the dataset.
geospatial_lat_max	float	1	9.9692099683868690e+36f	Describes a simple upper latitude limit; may be part of a 2- or 3-dimensional bounding region. Geospatial_lat_max specifies the northernmost latitude covered by the dataset.
geospatial_lon_min	float	1	9.9692099683868690e+36f	Describes a simple longitude limit; may be part of a 2- or 3-dimensional bounding region. geospatial_lon_min specifies the westernmost longitude covered by the dataset. See also geospatial_lon_max.
geospatial_lon_max	float	1	9.9692099683868690e+36f	Describes a simple longitude limit; may be part of a 2- or 3-dimensional bounding region. geospatial_lon_max specifies the easternmost longitude covered by the dataset. Cases where geospatial_lon_min is greater than geospatial_lon_max indicate the bounding box extends from geospatial_lon_max, through the longitude range discontinuity meridian (either the antimeridian for -180:180 values, or Prime Meridian for 0:360 values), to geospatial_lon_min; for example, geospatial_lon_min=170 and geospatial_lon_max=-175 incorporates 15 degrees of longitude (ranges 170 to 180 and -180 to -175).
time_coverage_start	string	1		Nominal start time. Describes the time of the first data point in the data set. Use the ISO 8601:2004 date format, preferably the

Name	Type	Size	Value	Description
				extended format as recommended in the Attribute Content Guidance section.
time_of_first_valid_obs	string	1		Describes the time of the first valid data point in the data set. Use the ISO 8601:2004 date extended format.
time_coverage_mid	string	1		Describes the midpoint between the nominal start and end times. Use the ISO 8601:2004 date format, preferably the extended format as recommended in the Attribute Content Guidance section.
time_coverage_end	string	1		Nominal end time. Describes the time of the last data point in the data set. Use ISO 8601:2004 date format, preferably the extended format as recommended in the Attribute Content Guidance section.
time_of_last_valid_obs	string	1		Describes the time of the last valid data point in the data set. Use the ISO 8601:2004 date extended format.
time_coverage_duration	string	1	P0000-00-00T00:06:00	Describes the duration of the data set. Use ISO 8601:2004 duration format, preferably the extended format as recommended in the Attribute Content Guidance section.
product_name_duration	string	1	m06	Product duration as it appears in product_name (m06 means six minutes)
creator_type	string	1	institution	Specifies type of creator with one of the following: 'person', 'group', 'institution', or 'position'. If this attribute is not specified, the creator is assumed to be a person.
creator_institution	string	1	Unassigned	The institution of the creator; should uniquely identify the creator's institution. This attribute's value should be specified even if it matches the value of publisher_institution, or if creator_type is institution.
product_version	string	1	vxx.xx.xx	Version identifier of the data file or product as assigned by the data creator. For example, a new algorithm or methodology could result in a new product_version.

Name	Type	Size	Value	Description
keywords_vocabulary	string	1	GCMD:GCMD Keywords	If you are using a controlled vocabulary for the words/phrases in your "keywords" attribute, this is the unique name or identifier of the vocabulary from which keywords are taken. If more than one keyword vocabulary is used, each may be presented with a prefix and a following comma, so that keywords may optionally be prefixed with the controlled vocabulary key. Example: 'GCMD:GCMD Keywords, CF:NetCDF COARDS Climate and Forecast Standard Names'.
platform	string	1	AQUA > Earth Observing System	Name of the platform(s) that supported the sensor data used to create this data set or product. Platforms can be of any type, including satellite, ship, station, aircraft or other. Indicate controlled vocabulary used in platform_vocabulary.
platform_vocabulary	string	1	GCMD:GCMD Keywords	Controlled vocabulary for the names used in the "platform" attribute.
product_name_platform	string	1	AQUA	Platform name as it appears in product_name
instrument	string	1	AIRS > Atmospheric Infrared Sounder	Name of the contributing instrument(s) or sensor(s) used to create this data set or product. Indicate controlled vocabulary used in instrument_vocabulary.
instrument_vocabulary	string	1	GCMD:GCMD Keywords	Controlled vocabulary for the names used in the "instrument" attribute.
product_name_instr	string	1	AIRS	Instrument name as it appears in product_name
product_name	string	1		Canonical fully qualified product name (official file name)
product_name_variant	string	1	std	Processing variant identifier as it appears in product_name. 'std' (shorthand for 'standard') is to be the default and should be what is seen in all public products.
product_name_version	string	1	vxx_xx_xx	Version number as it appears in product_name (v01_00_00)
product_name_producer	string	1	T	Production facility as it appears in product_name (single character) 'T' is the default, for unofficial local test products

Name	Type	Size	Value	Description
product_name_timestamp	string	1	yymmddhhmmss	Processing timestamp as it appears in product_name (yymmddhhmmss)
product_name_extension	string	1	nc	File extension as it appears in product_name (typically nc)
granule_number	ushort	1		granule number of day (1-240)
product_name_granule_number	string	1	g000	zero-padded string for granule number of day (g001-g240)
gran_id	string	1	yyyymmddThhmm	Unique granule identifier yyyymmddThhmm of granule start, including year, month, day, hour, and minute of granule start time
geospatial_lat_mid	float	1	9.9692099683868690e+36f	granule center latitude
geospatial_lon_mid	float	1	9.9692099683868690e+36f	granule center longitude
featureType	string	1	point	structure of data in file
data_structure	string	1	swath	a character string indicating the internal organization of the data with currently allowed values of 'grid', 'station', 'trajectory', or 'swath'. The 'structure' here generally describes the horizontal structure and in all cases data may also be functions, for example, of a vertical coordinate and/or time. (If using CMOR pass this in a call to cmor_set_cur_dataset_attribute.)
cdm_data_type	string	1	Swath	The data type, as derived from Unidata's Common Data Model Scientific Data types and understood by THREDDS. (This is a THREDDS "dataType", and is different from the CF NetCDF attribute 'featureType', which indicates a Discrete Sampling Geometry file in CF.)
id	string	1	Unassigned	An identifier for the data set, provided by and unique within its naming authority. The combination of the "naming authority" and the "id" should be globally unique, but the id can be globally unique by itself also. IDs can be URLs, URNs, DOIs, meaningful text strings, a local key, or any other unique string of characters. The id should not include white space characters.

Name	Type	Size	Value	Description
naming_authority	string	1	Unassigned	The organization that provides the initial id (see above) for the dataset. The naming authority should be uniquely specified by this attribute. We recommend using reverse-DNS naming for the naming authority; URIs are also acceptable. Example: 'edu.ucar.unidata'.
identifier_product_doi	string	1	Unassigned	digital signature
identifier_product_doi_authority	string	1	Unassigned	digital signature source
algorithm_version	string	1		The version of the algorithm in whatever format is selected by the developers. After the main algorithm name and version, versions from multiple sub-algorithms may be concatenated with semicolon separators. (ex: 'CCAST 4.2; BB emis from MIT 2016-04-01') Must be updated with every delivery that changes numerical results.
production_host	string	1		Identifying information about the host computer for this run. (Output of linux "uname -a" command.)
format_version	string	1	v02.02.59	Format version.
input_file_names	string	1		Semicolon-separated list of names or unique identifiers of files that were used to make this product. There will always be one space after each semicolon. There is no final semicolon.
input_file_types	string	1		Semicolon-separated list of tags giving the role of each input file in input_file_names. There will always be one space after each semicolon. There is no final semicolon.
input_file_dates	string	1		Semicolon-separated list of creation dates for each input file in input_file_names. There will always be one space after each semicolon. There is no final semicolon.
orbitDirection	string	1		Orbit is ascending and/or descending. Values are "Ascending" or "Descending" if the entire granule fits that description. "NorthPole" and "SouthPole" are used for polar-crossing granules. "NA" is used when a determination cannot be made.

Name	Type	Size	Value	Description
day_night_flag	string	1		Data is day or night. "Day" means subsatellite point for all valid scans has solar zenith angle less than 90 degrees. "Night" means subsatellite point for all valid scans has solar zenith angle greater than 90 degrees. "Both" means the dataset contains valid observations with solar zenith angle above and below 90 degrees. "NA" means a value could not be determined.
AutomaticQualityFlag	string	1	Missing	'Passed': all valid data with no gaps or quality issues; 'Suspect': some gaps or quality issues; 'Failed': no valid data
AutomaticQualityFlagExplanation	string	1	'Passed': all valid data with no gaps or quality issues; 'Suspect': some gaps or quality issues; 'Failed': no valid data	A text explanation of the criteria used to set AutomaticQualityFlag; including thresholds or other criteria.
qa_pct_data_missing	float	1		Percentage of expected observations that are missing.
qa_pct_data_geo	float	1		Percentage of expected observations that are successfully geolocated.
qa_pct_data_sci_mode	float	1		Percentage of expected observations that were taken while the instrument was in science mode and are successfully geolocated.
qa_no_data	string	1	TRUE	A simple indicator of whether this is an "empty" granule with no data from the instrument. "TRUE" or "FALSE".
title	string	1	Aqua AIRS Level 2 JoSFRA Retrieval Standard: Atmosphere cloud and surface geophysical state per footprint	a succinct description of what is in the dataset. (= ECS long name)
summary	string	1	The Level-2 JoSFRA product includes atmospheric state retrieval products from the JoSFRA algorithm for one six-minute interval. These include temperature and water vapor profiles as well as cloud and surface products and minor gases.	A paragraph describing the dataset, analogous to an abstract for a paper.
shortname	string	1	SNDRAQIL2JSFRET	ECS Short Name

Name	Type	Size	Value	Description
product_group	string	1	l2_airs	The group name to be used for this product when it is collected in a multi-group file type, like SNO or calsub
metadata_link	string	1	Unassigned	A URL that gives the location of more complete metadata. A persistent URL is recommended for this attribute.
references	string	1	Irion, F. W., et al., Single-footprint retrievals of temperature, water vapor and cloud properties from AIRS, Atmos. Meas. Tech., 11, 971-995, 2018; https://doi.org/10.5194/amt-11-971-2018	ATDB and design documents describing processing algorithms. Can be empty.
contributor_name	string	1	Fredrick W. Irion, JPL; L. Larrabee Strow, UMBC	The names of any individuals or institutions that contributed to the creation of this data.
contributor_role	string	1	Retrieval PI; Forward Model PI	The roles of any individuals or institutions that contributed to the creation of this data.

aux Group

Variables for the aux group

Name	Type	Dimensions	Description	Units	Ancillary Variables
surf_ir_emis_logistic	float32	atrack, xtrack, surf_wnum_ir	infrared surface emissivity as transformed by the logistic function for internal use in the retrieval	unitless	err
fg_surf_ir_emis	float32	atrack, xtrack, surf_wnum_ir	First guess for infrared surface emissivity	unitless	
fg_surf_ir_emis_logistic	float32	atrack, xtrack, surf_wnum_ir	First guess for infrared surface emissivity as transformed by the logistic function for internal use in the retrieval	unitless	
prior_surf_pres	float32	atrack, xtrack	surface pressure from forecast	Pa	
ret_proc_time	float32	atrack, xtrack	Time needed for retrieval processing	seconds	

Name	Type	Dimensions	Description	Units	Ancillary Variables
cost_func_step_one	float32	atrack, xtrack	Cost function, step one: everything except water vapor	unitless	
cost_func_step_two	float32	atrack, xtrack	Cost function, step two: water vapor	unitless	
stop_code_step_one	int16	atrack, xtrack	Stop code step one: everything except water vapor. These are the stop codes for the L-M solver and other parts of the retrieval. Any stop_code greater than 2 is nonconvergent. CONVERGENGE_NOT_OBTAINED_KEEP_ITERATING = 0; NORMAL_EXIT = 1; MAX_NUM_ITERATIONS_REACHED = 2; DELTA_NEXT_LT_0_001_AND_RHO_LT_0_001 = 3; TWO_NORM_OF_JACOBIAN_IS_NAN = 5; UNKNOWN_VALUE_ERROR = 7; CHISQ_GT_1E5_AFTER_3RD_ITERATION = 8; CHISQ_GT_1E4_AFTER_1ST_ITERATION = 10; NEG_VALUE_FOR_H2O_SLAB = 11; OUTPUT_FILE_ALREADY_EXISTS = 20; LAND_FRAC_GT_1PERCENT_FOR_OCEAN_ONLY = 30; LAND_FRAC_LT_99PERCENT_FOR_LAND_ONLY = 35; CIRRUS_SIZE_OUTSIDE_ALLOWED_RANGE = 100; CLD_T_TEMPERATURE_ITERATION_LT_180K = 150; NAN_IN_JACOBIAN = 200; ERROR_IN_QR_DECOMPOSITION = 210; LAMBDA_LE_0_IN_SOLVER = 220; UNKNOWN_ERROR_IN_SOLVER = 999		
stop_code_step_two	int16	atrack, xtrack	Stop code step two: water vapor. These are the stop codes for the L-M solver and other parts of the retrieval. Any stop_code greater than 2 is nonconvergent. CONVERGENGE_NOT_OBTAINED_KEEP_ITERATING = 0; NORMAL_EXIT = 1; MAX_NUM_ITERATIONS_REACHED = 2; DELTA_NEXT_LT_0_001_AND_RHO_LT_0_001 = 3; TWO_NORM_OF_JACOBIAN_IS_NAN = 5; UNKNOWN_VALUE_ERROR = 7; CHISQ_GT_1E5_AFTER_3RD_ITERATION = 8; CHISQ_GT_1E4_AFTER_1ST_ITERATION = 10; NEG_VALUE_FOR_H2O_SLAB = 11; OUTPUT_FILE_ALREADY_EXISTS = 20; LAND_FRAC_GT_1PERCENT_FOR_OCEAN_ONLY = 30; LAND_FRAC_LT_99PERCENT_FOR_LAND_ONLY = 35; CIRRUS_SIZE_OUTSIDE_ALLOWED_RANGE = 100; CLD_T_TEMPERATURE_ITERATION_LT_180K = 150; NAN_IN_JACOBIAN = 200; ERROR_IN_QR_DECOMPOSITION = 210; LAMBDA_LE_0_IN_SOLVER = 220; UNKNOWN_ERROR_IN_SOLVER = 999		
num_iter_step_one	ushort	atrack, xtrack	Number of iterations in step one (everything except water vapor)	unitless	
num_iter_step_two	ushort	atrack, xtrack	Number of iterations in step two (water vapor)	unitless	
imgr_surf_temp	float32	atrack, xtrack	radiative temperature of the surface from MODIS or other imager on AIRS FOV	kelvin	

Name	Type	Dimensions	Description	Units	Ancillary Variables
imgr_cld_top_temp	float32	atrack, xtrack	first guess cloud top temperature from MODIS or other imager on AIRS FOV	kelvin	
imgr_cld_optical_depth	float32	atrack, xtrack	first guess cloud optical depth from MODIS or other imager on AIRS FOV	unitless	
imgr_cld_eff_radius	float32	atrack, xtrack	first guess cloud effective radius from MODIS or other imager on AIRS FOV	m	
imgr_heavy_aerosol_flag	float32	atrack, xtrack	Heavy aerosol flag from MODIS or other imager on AIRS FOV		
imgr_snow_ice_flag	float32	atrack, xtrack	Snow/ice flag from MODIS or other imager on AIRS FOV		
imgr_thin_cirrus_flag	float32	atrack, xtrack	Thin cirrus flag from MODIS or other imager on AIRS FOV		
cld_phase_bin_total	int32	atrack, xtrack	Cloud phase test binary total. See references. binTotal(start) = 0; if Tb_960 < 235.: binTotal += 1; if (Tb_1231 - Tb_960) > 0.: binTotal += 2,; if (Tb_1231 - Tb_930) > 1.75: binTotal += 4; if (Tb_1227 - Tb_960) > -0.5: binTotal += 8; if (Tb_1231 - Tb_960) < -1.: binTotal += 16; if (Tb_1231 - Tb_930) < -0.6: binTotal += 32		
cld_phase_sum	int32	atrack, xtrack	Cloud phase test sum. See references. binTotal(start) = 0; if Tb_960 < 235.: binTotal += 1; if (Tb_1231 - Tb_960) > 0.: binTotal += 2,; if (Tb_1231 - Tb_930) > 1.75: binTotal += 4; if (Tb_1227 - Tb_960) > -0.5: binTotal += 8; if (Tb_1231 - Tb_960) < -1.: binTotal += 16; if (Tb_1231 - Tb_930) < -0.6: binTotal += 32		
ice_cld_total_score	int32	atrack, xtrack	Cloud ice phase test sum. See references. ice_cld_total_score (start) = 0; if Tb_960 < 235.: ice_cld_total_score += 1; if (Tb_1231 - Tb_960) > 0.: ice_cld_total_score += 1; if (Tb_1231 - Tb_930) > 1.75: ice_cld_total_score += 1; if (Tb_1227 - Tb_960) > -0.5: ice_cld_total_score += 1		
liq_cld_total_score	int32	atrack, xtrack	Cloud liquid phase test sum. See references. liq_cld_total_score (start) = 0; if (Tb_1231 - Tb_960) < -1.: liq_cld_total_score -= 1; if (Tb_1231 - Tb_930) < -0.6: liq_cld_total_score -= 1		
fg_air_temp	float32	atrack, xtrack, air_temp_pres	first guess for air temperature profile on retrieval basis layers	kelvin	
fg_spec_hum	float32	atrack, xtrack, h2o_vap_pres	first guess for mass fraction of water vapor in moist air	kg / kg	
fg_rel_hum	float32	atrack, xtrack, h2o_vap_pres	first guess relative humidity over equilibrium phase	unitless	

Name	Type	Dimensions	Description	Units	Ancillary Variables
fg_o3_vmr	float32	atrack, xtrack, o3_pres	first guess ozone VMR	unitless	
fg_co2_vmr	float32	atrack, xtrack, co2_pres	first guess carbon dioxide VMR	m3 / m3	
fg_cld_top_temp	float32	atrack, xtrack	first guess cloud top temperature from MODIS or other source, as indicated in cld_top_temp_fg_src	kelvin	
cld_top_temp_fg_src	byte	atrack, xtrack	cloud top temperature first guess source: -1 = unknown; 0 = not applicable; 1 = MODIS average; 2 = assumed; 3 = Cld T assumed for cirrus; 4 = Cld T from AIRS brightness temperatures; 5 = AIRS PGE L2; 7 = Climatology; 8 = No cloud		
fg_cld_optical_depth	float32	atrack, xtrack	first guess cloud optical depth from MODIS or other source, as indicated by cld_optical_depth_fg_src	unitless	
cld_optical_depth_fg_src	byte	atrack, xtrack	cloud optical depth first guess source: -1 = unknown; 0 = not applicable; 1 = MODIS average; 2 = assumed; 5 = AIRS PGE L2; 6 = Cld OD calculated from MODIS cld mask cloudiness; 7 = Climatology; 8 = No cloud		
fg_cld_eff_radius	float32	atrack, xtrack	first guess cloud effective radius from MODIS or other source, as indicated in cld_eff_radius_fg_src	m	
cld_eff_radius_fg_src	byte	atrack, xtrack	cloud effective radius first guess source: -1 = unknown; 0 = not applicable; 1 = MODIS average; 2 = assumed; 5 = AIRS PGE L2; 7 = Climatology; 8 = No cloud		
fg_cld_rad_wlen	float32		wavelength for cloud optical depth	m	
fg_surf_temp	float32	atrack, xtrack	radiative temperature of the surface from the first guess	kelvin	