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

README Document for

A Multi-Sensor Water Vapor Climate Data Record Using Cloud Classification

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Goddard Earth Sciences Data and Information Services Center (GES DISC)
http://disc.gsfc.nasa.gov
NASA Goddard Space Flight Center
Code 610.2
Greenbelt, MD 20771 USA

Prepared By:

Gerald Manipon

Name
GES DISC
GSFC Code 610.2
03/19/2012

Date

JPL

Name

Reviewed By:

Reviewer Name
GES DISC
GSFC Code 613.2

Date

Goddard Space Flight Center
Greenbelt, Maryland

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2010-10-07	Added initial content.	Gerald Manipon
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2011-03-01	Mapped data types to s4pa short/long names and collection versions. Clarified AMSU, AIRS, CloudSat footprints.	Gerald Manipon
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1.0 Introduction

This document provides basic information for using the WVCC (Water Vapor Cloud Climatology) AIRS-CloudSat merged dataset.

The WVCC AIRS-CloudSat merged dataset consists of products generated for the focus on multi-sensor water vapor climatology using cloud classification.

1.1 Dataset/Mission Instrument Description

The basic task is to bring together retrievals of water vapor and cloud properties from multiple "A-train" instruments (AIRS & CloudSat), classify each "scene" (instrument look) using the cloud information, and develop a merged, multi-sensor climatology of atmospheric water vapor as a function of altitude, stratified by the cloud classes. This is a large science analysis project that will require the use of SciFlo technologies to discover and organize all of the datasets, move and cache datasets as required, find space/time "matchups" between pairs of instruments, and process years of satellite data to produce the climate data records.

Figure 1.1: The A-train

1.1.1 AIRS & AMSU

AIRS is a continuously operating cross-track scanning sounder, consisting of a telescope that feeds an echelle spectrometer. The AIRS infrared spectrometer acquires 2378 spectral samples at resolutions, $\lambda/\Delta\lambda$, ranging from 1086 to 1570, in three bands: 3.74 m to 4.61 m, 6.20 m to 8.22 m, and 8.8 m to 15.4 m. The spatial footprint of the infrared channels is 1.1° in diameter, which corresponds to about 15x15 km in the nadir.

AMSU-A is a 15-channel microwave temperature sounder implemented as two independently operated modules. Module 1 (AMSU-A1) has 12 channels in the 50-58 GHz oxygen absorption band which provide the primary temperature sounding capabilities and 1 channel at 89 GHz which provides surface and moisture information. Module 2 (AMSU-A2) has 2 channels: one at 23.8 GHz and one at 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. AMSU-A scans three times as slowly as AIRS (once per 8 seconds), and its footprints are approximately three times as large as those of AIRS (45 km at nadir). This results in three AIRS scans per AMSU-A scans and nine AIRS footprints per AMSU-A footprint.

1.1.2 CloudSat

The Cloud Profiling Radar (CPR) on CloudSat is a 94-GHz nadir-looking radar which measures the power backscattered by clouds as a function of distance from the radar. The CloudSat data footprint is approximately 1.7 km along-track by 1.3 km across-track. A granule is one orbit of data beginning at the first profile on or after the equator on the descending node. There are 125 vertical bins, each one approximately 240 m thick. There are approximately 36,383 profiles per granule.

1.1.3 SciFlo

SciFlo is a semantically-enabled ("smart") Grid Workflow system that ties together a peer-to-peer network of computers into an efficient engine for distributed computation. The SciFlo workflow engine enables scientists to do multi-instrument Earth Science by assembling remotely-invokable Web Services (SOAP or http GET URLs), native executables, command-line scripts, and Python codes into a distributed computing flow. SciFlo also deploys a variety of Data Grid services to: query datasets in space and time, locate & retrieve on-line data granules, and provide on-the-fly variable and spatial subsetting.

In processing AIRS-CloudSat matchups, the EOSService:geoRegionQuery() web service is used to query both CloudSat and AIRS datasets for granule identification and location (Figure 1.2).

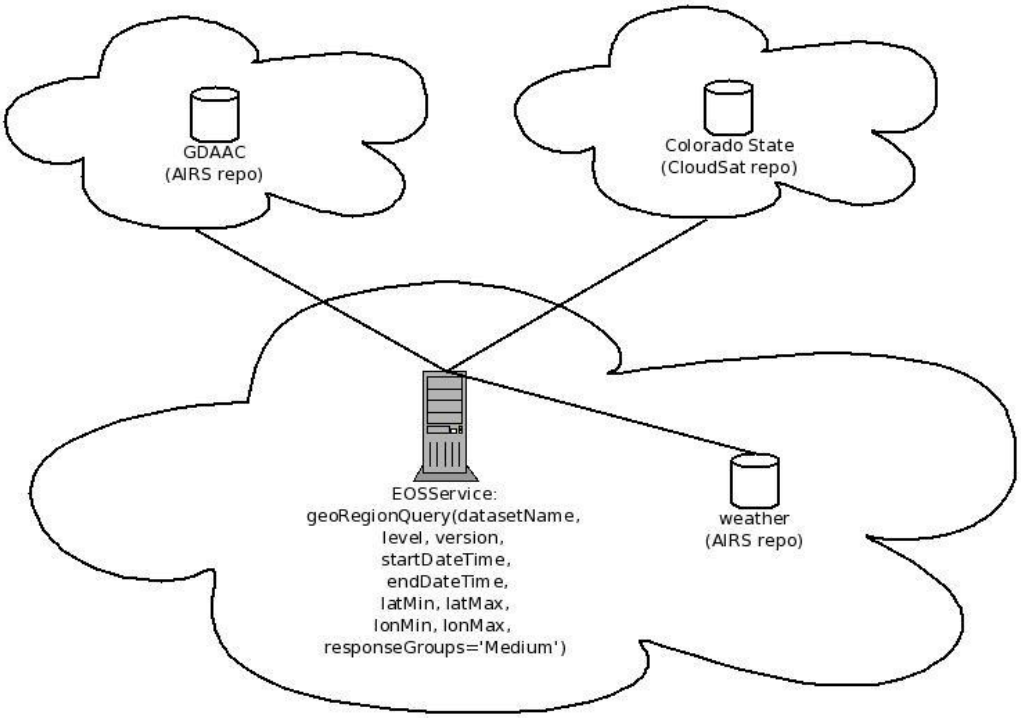

Figure 1.2: geoRegionQuery()

1.2 Algorithm Background

Production of the AIRS-CloudSat merged dataset is divided into two workflows producing the following intermediate and final products:

1) Footprint Matchups
    a. Matchup indices indexed by CloudSat granule (pickle & text)
    b. Matchup indices indexed by AIRS granule (pickle & text)
2) Variable Subsetting and Aggregation
    a. Subset AIRS and CloudSat variables indexed by AIRS granule (netCDF4)
    b. (optional) plots of AIRS, AMSU, & CloudSat granule and matched footprints (png)

Each workflow and its associated products are maintained as separate versions. As of this writing, both workflows are at v3.1.

1.2.1 Footprint Matchup

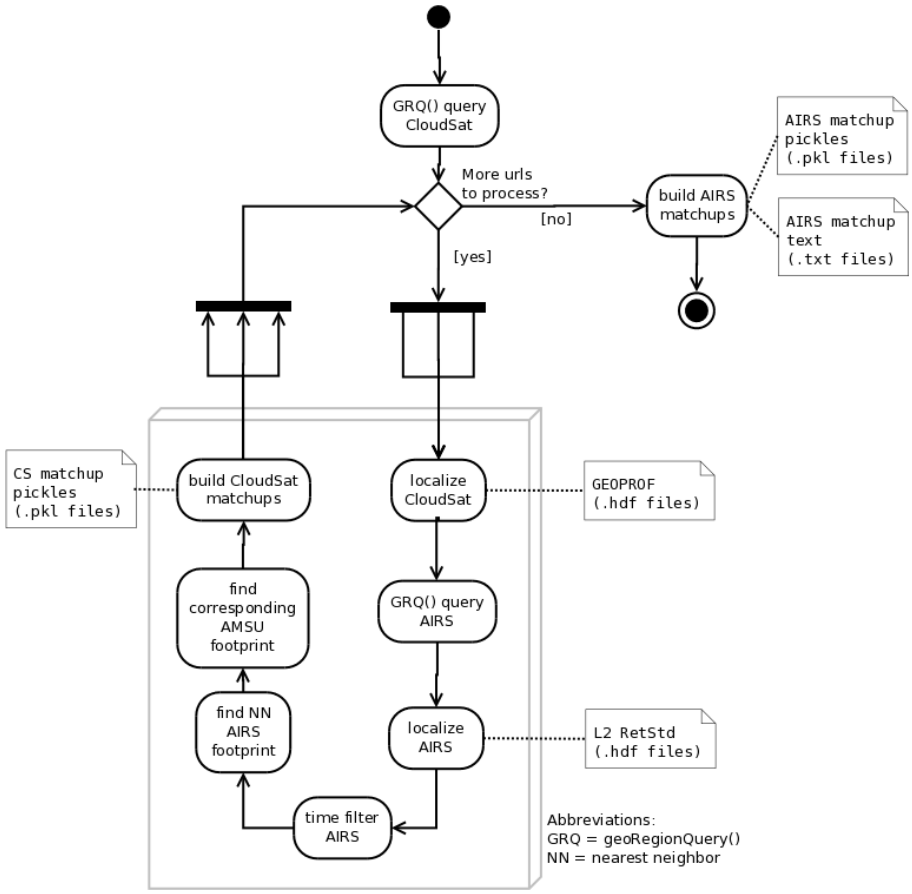

Figure 1.3: Footprint Matchup Activity Diagram

Figure 1.3 shows a high-level activity diagram of the footprint matchup workflow. The list of CloudSat granules drives the workflow and spawns concurrent SciFlo Work Units (workUnits hereafter) to handle each granule matchup. Note that aside from the products mentioned above, workUnit execution here results in the localization & caching of AIRS L2 RetStd and CloudSat GEOPROF granules.

The matchup indices for each CloudSat granule is collected by brute-force iteration over the CloudSat footprints and extracted from the nearest AIRS footprint. The AMSU footprint that contains the matched AIRS footprint is also recorded. The following code snippet in Python implements the nearest neighbor algorithm used in the matchup:

```
import numpy as N

MAJOR_AXIS_RADIUS = 6378.137
MINOR_AXIS_RADIUS = 6356.7523142
RADIUS_EARTH = (2 * MAJOR_AXIS_RADIUS + MINOR_AXIS_RADIUS)/3.
DEG2RAD = N.pi/180.

def getDistance(lon1, lat1, lon2, lat2):
    """
    Return distance in kilometers between a point specified by
    lon1/lat1 and another point or array of points specified by lon2/lat2.
    """

    #calculate diffs
    dLat = lat2 - lat1
    dLon = lon2 - lon1

    #calculate distance using great circle
    return 2. * RADIUS_EARTH * \
        N.arcsin( N.sqrt( \
        (N.sin(dLat * DEG2RAD/2.))**2 \
        + N.cos(lat2 * DEG2RAD) \
        * N.cos(lat1 * DEG2RAD) \
        * (N.sin(dLon * DEG2RAD/2.))**2 \
    ))

...

#match AMSU footprint
amsuLon = a['Longitude']                                    #45x30 Longitude array from L2 RetStd
amsuLat = a['Latitude']                                     #45x30 Latitude array from L2 RetStd
amsuDist = getDistance(csLon, csLat, amsuLon, amsuLat)
closestAmsuIdx = N.unravel_index(amsuDist.argmin(), amsuDist.shape)    #get index of closest AMSU footprint

#match AIRS footprint
airsLon = a['lonAIRS']                                      #45x30x3x3 lonAIRS array from L2RetStd
airsLat = a['latAIRS']                                      #45x30x3x3 latAIRS array from L2RetStd
airsDist = getDistance(csLon, csLat, airsLon, airsLat)
closestAirsIdx = N.unravel_index(airsDist.argmin(), airsDist.shape)        #get index of closest AIRS footprint
```

After the CloudSat-AIRS matchup indices are collected and pickled, the matchup index text files, indexed by AIRS granules, are then generated.

The following example illustrates the matchups. Figure 1.4 shows a plot of the AIRS and AMSU footprints for AIRS granule AIRS.2006.11.08.227.L2.RetStd.v5.0.14.0.G07318121028.hdf and most of the CloudSat footprints for granule 2006312211510_02833_CS_2B-GEOPROF_GRANULE_P_R04_E02.hdf:

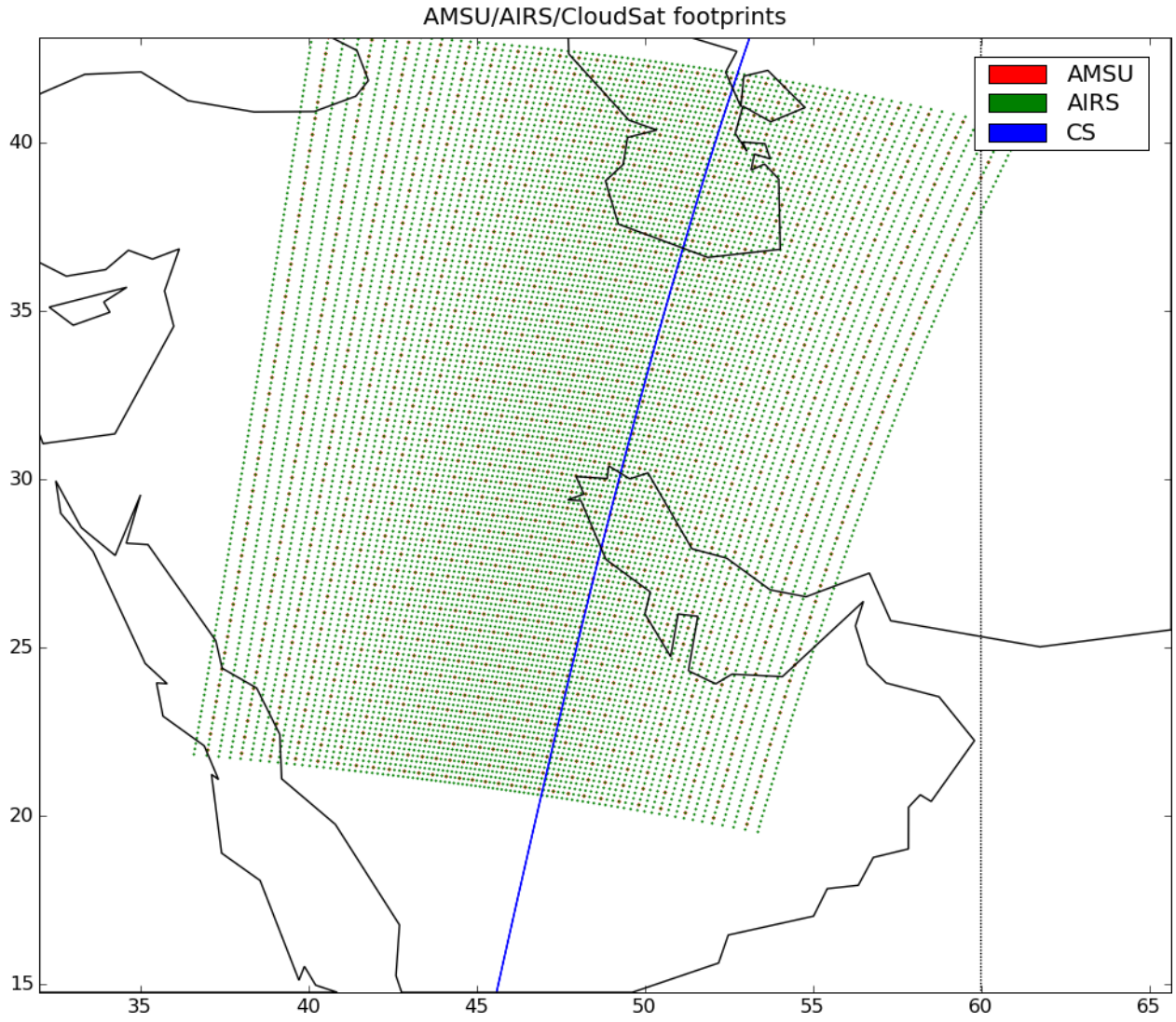

Figure 1.4: Footprint Plot

Figure 1.5 shows the resulting matched-up AIRS, AMSU, and CloudSat footprints:

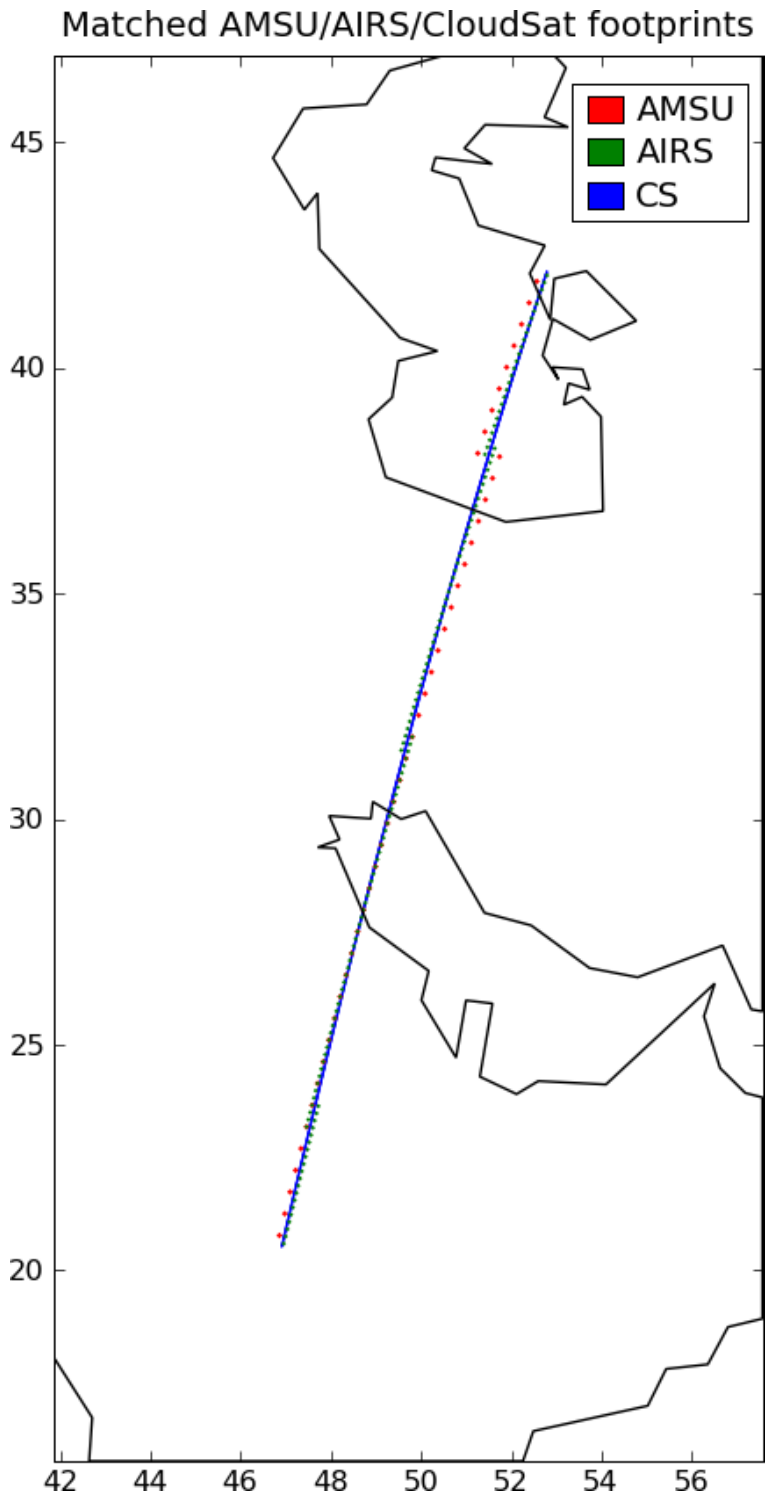

Figure 1.5: Matched Footprints Plot

1.2.2 Variable Subsetting and Aggregation

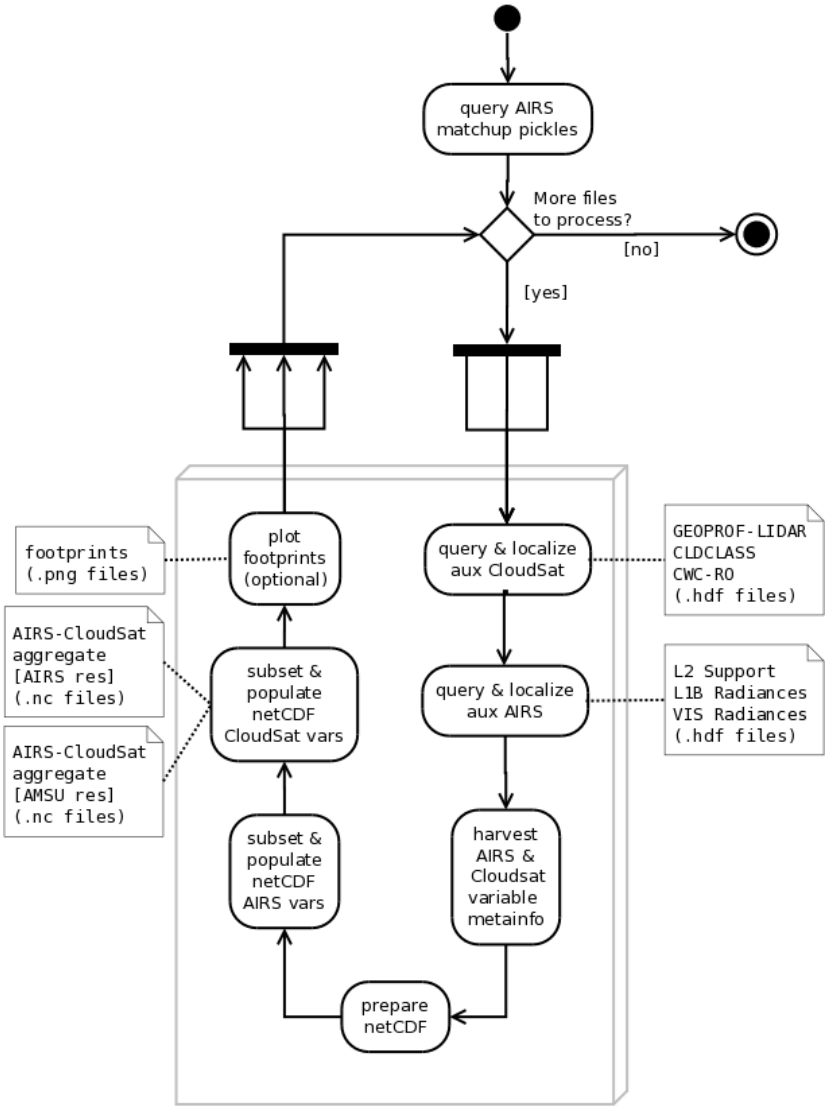

Figure 1.6: Variable Subsetting and Aggregation Activity Diagram

Figure 1.6 shows a high-level activity diagram of the subset & aggregation workflow. The list of AIRS matchups drives the workflow and spawns concurrent workUnits to handle these tasks. Note that execution of this workflow results in the localization & caching of additional AIRS (L2 Support, L1B Radiances, VIS Radiances) and CloudSat (GEOPROF-LIDAR, CLDLCLASS, CWC-RO) granules. Optionally, footprint plots may be generated to validate the matchup indices.

What dataset (AIRS & CloudSat) product variables are included in the final merged product is driven by an xml configuration file generated as a result of the WVCC variable voting application (http://sciflo.jpl.nasa.gov/wsgi/wvc_varlister/).

1.3 Data Disclaimer

For any questions regarding this dataset, please contact Gerald Manipon at Geraldjohn.M.Manipon@jpl.nasa.gov.

For detailed information on the v5 AMSU/AIRS data, consult the documentation located at http://disc.sci.gsfc.nasa.gov/AIRS/documentation.

For detailed information on the R04 CloudSat data, consult the documentation located at http://www.cloudsat.cira.colostate.edu/dataHome.php.

For information on the directory structure and filename conventions used for the AIRS-CloudSat matchups, consult the documentation located at http://www.cloudsat.cira.colostate.edu/dataHome.php.

For information and access tools pertaining to NetCDF, consult the documentation at http://www.unidata.ucar.edu/software/netcdf/.

For information on the Python programming language, consult the documentation at http://www.python.org.

2.0 Data Organization

The data consists of:

1) the AIRS-CloudSat matchup index files in text format
    - ShortName = 'AIRS_CPR_IND'
    - LongName = 'AIRS-CloudSat cloud mask and radar reflectivities collocation indexes'
    - VersionID = '003'
2) the AIRS-CloudSat matched variables aggregated in NetCDF4 files
    a. Aggregate NetCDF4 files for AIRS variables in AIRS resolution
        - ShortName = 'AIRS_CPR_MAT'
        - LongName = 'AIRS-CloudSat cloud mask, radar reflectivities, and cloud classification matchups'
        - VersionID = '003'
    b. Aggregate NetCDF4 files for AIRS variables in AMSU resolution
        - ShortName = 'AIRSM_CPR_MAT'
        - LongName = 'AIRS-AMSU variables-CloudSat cloud mask, radar reflectivities, and cloud classification matchups'
        - VersionID = '003'

All products are indexed by AIRS granules thus for each day there are 240 files per product.

2.1 File Naming Convention

2.1.1 AIRS_CPR_IND (Matchup Index Text Files)

index-airs.aqua_cloudsat-*vm.m-yyyy.mm.dd.ggg*.txt

Where:
- m.m = algorithm version identifier is made up of major version and minor version, respectively.
- yyyy = 4 digit year number [2006 -].
- mm = 2 digit month number [01-12]
- dd = day of month [01-31]
- ggg = granule number [1-240]

Filename example: index-airs.aqua_cloudsat-v3.1-2006.06.15.167.txt

2.1.2 AIRS_CPR_MAT (Aggregate AIRS NetCDF4 Files)

matched-airs.aqua_cloudsat-*vm.m-yyyy.mm.dd.ggg*_airs.nc

Where:

- m.m = algorithm version identifier is made up of major version and minor version, respectively.
- yyyy = 4 digit year number [2006 -].
- mm = 2 digit month number [01-12]
- dd = day of month [01-31]
- ggg = granule number [1-240]

Filename example: matched-airs.aqua_cloudsat-v3.1-2006.06.15.185_airs.nc

2.1.3 AIRSM_CPR_MAT (Aggregate AMSU NetCDF4 Files)

matched-airs.aqua_cloudsat-*vm.m-yyyy.mm.dd.ggg*_amsu.nc

Where:

- m.m = algorithm version identifier is made up of major version and minor version, respectively.
- yyyy = 4 digit year number [2006 -].
- mm = 2 digit month number [01-12]
- dd = day of month [01-31]
- ggg = granule number [1-240]

Filename example: matched-airs.aqua_cloudsat-v3.1-2006.06.15.185_amsu.nc

2.2 File Format and Structure

The AIRS_CPR_IND (matchup index file) data type is in text format and contains the AIRS-CloudSat matchup indices in both AIRS and AMSU resolutions. An example from the following matchup file, index-airs.aqua_cloudsat-v3.1-2006.11.08.225.txt, will serve to explain its format:

AMSU footprint for AIRS granule 2006.11.08.225: (RetStd_row, RetStd_col)

CloudSat granule

Matching CloudSat footprint

# of CloudSat footprints matched to AMSU footprint

AIRS footprint for AIRS granule 2006.11.08.225: (RetStd_row, RetStd_col, ir_row, ir_column)

# of CloudSat footprints matched to AIRS footprint

```
(0, 14)
50 -- /data1/users/gmanipon/sensors/atrain/cloudsat/GEOPROF/R04/2006/312/2006312211510_02833_CS_2B-GEOPROF_GRANULE_P_R04_E02.hdf [28210, 28211, 28212, 28213, 28214, 28215, 28216, 28217, 28218, 28219, 28220, 28221, 28222, 28223, 28224, 28225, 28226, 28227, 28228, 28229, 28230, 28231, 28232, 28233, 28234, 28235, 28236, 28237, 28238, 28239, 28240, 28241, 28242, 28243, 28244, 28245, 28246, 28247, 28248, 28249, 28250, 28251, 28252, 28253, 28254, 28255, 28256, 28257, 28258, 28259]
(0, 14, 0, 1)
12 -- /data1/users/gmanipon/sensors/atrain/cloudsat/GEOPROF/R04/2006/312/2006312211510_02833_CS_2B-GEOPROF_GRANULE_P_R04_E02.hdf [28215, 28216, 28217, 28218, 28219, 28220, 28221, 28222, 28223, 28224, 28225, 28226]
(0, 14, 0, 2)
5 -- /data1/users/gmanipon/sensors/atrain/cloudsat/GEOPROF/R04/2006/312/2006312211510_02833_CS_2B-GEOPROF_GRANULE_P_R04_E02.hdf [28210, 28211, 28212, 28213, 28214]
(0, 14, 1, 1)
16 -- /data1/users/gmanipon/sensors/atrain/cloudsat/GEOPROF/R04/2006/312/2006312211510_02833_CS_2B-GEOPROF_GRANULE_P_R04_E02.hdf [28227, 28228, 28229, 28230, 28231, 28232, 28233, 28234, 28235, 28236, 28237, 28238, 28239, 28240, 28241, 28242]
(0, 14, 2, 1)
17 -- /data1/users/gmanipon/sensors/atrain/cloudsat/GEOPROF/R04/2006/312/2006312211510_02833_CS_2B-GEOPROF_GRANULE_P_R04_E02.hdf [28243, 28244, 28245, 28246, 28247, 28248, 28249, 28250, 28251, 28252, 28253, 28254, 28255, 28256, 28257, 28258, 28259]
```

The AIRS_CPR_MAT (aggregate AIRS file) data type is in NetCDF4 format (http://www.unidata.ucar.edu/software/netcdf/) and contains the CloudSat and AIRS variables of interest sliced along the matched CloudSat-AIRS footprints.

The AIRSM_CPR_MAT (aggregate AMSU file) data type is in NetCDF4 format and contains the CloudSat and AIRS variables of interest sliced along the matched CloudSat-AMSU footprints.

In both aggregate products, the original variable names from each source's dataset are preserved along with the containing HDF group by utilizing the following HDF grouping structure:

<dataset>/<product>/<variable name>

Where:
- dataset = either AIRS or CloudSat
- product = for AIRS either RetStd, RetSup, Radiances, or VIS.Radiances; for CloudSat either GEOPROF, GEOPROF-LIDAR, CLDCLASS, or CWC-RO
- variable name = variable name in source dataset product

variable name examples: AIRS/RetStd/CldFrcStd, AIRS/Radiances/Longitude, CloudSat/GEOPROF/MODIS_scene_var, CloudSat/CLDCLASS/Data_status

2.3 Key Science Data Fields

Important notes on variable names

The variables listed below are replicated from AIRS, CloudSat or CALIPSO data products. Variable names indicate their sources; the leading field of the variable describes the instrument(s), the second field is the source file, and the third field is identical to the names in the corresponding source file.

Current instrument sources are AIRS, CloudSat and CALIPSO.

Current file sources are

Radiances: AIRS/AMSU radiances products (Level 1b). All AIRS/AMSU variables are described in the document AIRS *Version 4.0 Processing Files Description*, JPL D-38428, June July 2007.

RetStd: AIRS/AMSU Standard Product (Level 2 retrievals). All AIRS/AMSU variables are described in the document AIRS *Version 4.0 Processing Files Description*, JPL D-38428, June July 2007.

RetSup: AIRS/AMSU Support Products (L2). All AIRS/AMSU variables are described in the document AIRS *Version 4.0 Processing Files Description*, JPL D-38428, June July 2007.

GEOPROF: CloudSat radar geolocation information. See *CloudSat Standard Data Products Handbook*, May 18, 2006.

GEOPROF-LIDAR: CALIPSO lidar geolocation information. See *CloudSat Standard Data Products Handbook*, May 18, 2006.

CLDCLASS: CloudSat cloud classes. See *Level 2 Cloud Scenario Classification Product Process Description and Interface Control Document*, Version: 4.0, March 1, 2005.

***Example**:* variable AIRS/RetStd/latAIRS

Source instruments: AIRS (designates the AIRS/AMSU instrument suite).

RetStd: File source is AIRS/AMSU Standard Product (Level 2 retrievals).

latAIRS: latitudes of AIRS spectral within an AMSU FOV (dimensioned 3 X 3).

The following table lists the variables in the AIRS_CPR_MAT (aggregate AIRS file) data type:

Variable name	**Long name (units)**
AIRS/RetStd/CldFrcStd	Comment: This is a retrieved quantity, but reported at the same locations as the AIRS spectra. All other AIRS/AMSU retrieved quantities are reported at the AMSU resolution (see next table).
AIRS/RetStd/CldFrcStdErr	
AIRS/RetStd/spectral_clear_indicator	
AIRS/RetStd/latAIRS	
AIRS/RetStd/dust_flag	
AIRS/RetStd/lonAIRS	
AIRS/Radiances/satazi	
AIRS/Radiances/spectral_freq	
AIRS/Radiances/scanang	
AIRS/Radiances/landFrac_err	
AIRS/Radiances/satzen	
AIRS/Radiances/dust_score	
AIRS/Radiances/landFrac	
AIRS/Radiances/solzen	
AIRS/Radiances/Longitude	
AIRS/Radiances/dust_flag	
AIRS/Radiances/spectral_clear_indicator	
AIRS/Radiances/Time	

AIRS/Radiances/Latitude	
AIRS/Radiances/radiances	
AIRS/Radiances/solazi	
CloudSat/GEOPROF/nray:2B-GEOPROF	
CloudSat/GEOPROF/nbin:2B-GEOPROF	
CloudSat/GEOPROF/Radar_Reflectivity	Radar Reflectivity Factor (dBZe)
CloudSat/GEOPROF/MODIS_scene_var	MODIS scene variability ()
CloudSat/GEOPROF/Sigma-Zero	Sigma-Zero (dB*100)
CloudSat/GEOPROF/MODIS_cloud_flag	MOD35_bit_2and3_cloud_flag (None)
CloudSat/GEOPROF/MODIS_scene_char	MODIS scene characterizations ()
CloudSat/GEOPROF/Longitude	Spacecraft Longitude (degrees)
CloudSat/GEOPROF/Height	Height of range bin in Reflectivity/Cloud Mask above reference surface (~ mean sea level). (m)
CloudSat/GEOPROF/Clutter_reduction_flag	Clutter_reduction_flag ()
CloudSat/GEOPROF/Profile_time	Seconds since the start of the granule. (seconds)
CloudSat/GEOPROF/CPR_Cloud_mask	CPR Cloud Mask ()
CloudSat/GEOPROF/Data_quality	Data Quality (--)
CloudSat/GEOPROF/MODIS_Cloud_Fraction	MODIS 250m Cloud Fraction ()
CloudSat/GEOPROF/Latitude	Spacecraft Latitude (degrees)
CloudSat/GEOPROF/Pitch_offset	Nominal satellite pitch angle offset from nadir (degrees)
CloudSat/GEOPROF/UTC_start	UTC seconds since 00:00 Z of the first profile (seconds)
CloudSat/GEOPROF/Navigation_land_sea_flag	Land Sea Flag (--)
CloudSat/GEOPROF/SurfaceHeightBin_fraction	SurfaceHeightBin_fraction (none)
CloudSat/GEOPROF/Data_status	Data status flags (--)
CloudSat/GEOPROF/SurfaceHeightBin	SurfaceHeightBin_fraction Location of Surface Bin as determined by 1B CPR algorithm. The value here is shifted (as Height). (none)
CloudSat/GEOPROF-LIDAR/UncertaintyCF	Uncertainty of Cloud Fraction ()
CloudSat/GEOPROF-LIDAR/LayerBase	Height of Layer Base (m)
CloudSat/GEOPROF-LIDAR/DEM_elevation	Digital Elevation Map (meters)
CloudSat/GEOPROF-LIDAR/nbin:2B-GEOPROF-LIDAR	
CloudSat/GEOPROF-LIDAR/Data_targetID	CPR bus orientation (target ID) (--)
CloudSat/GEOPROF-LIDAR/ncloud:2B-GEOPROF-LIDAR	
CloudSat/GEOPROF-LIDAR/Longitude	Spacecraft Longitude (degrees)
CloudSat/GEOPROF-LIDAR/Height	Height of range bin in Reflectivity/Cloud Mask above reference surface (~ mean sea level). (m)
CloudSat/GEOPROF-LIDAR/FlagTop	Flag of layer top ()
CloudSat/GEOPROF-LIDAR/Latitude	Spacecraft Latitude (degrees)
CloudSat/GEOPROF-LIDAR/CloudLayers	Number of hydrometeor layers ()
CloudSat/GEOPROF-LIDAR/Data_quality	Data Quality (--)
CloudSat/GEOPROF-LIDAR/Vertical_binsize	(m)
CloudSat/GEOPROF-LIDAR/CloudFraction	Cloud Fraction ()
CloudSat/GEOPROF-LIDAR/nray:2B-GEOPROF-LIDAR	

CloudSat/GEOPROF-LIDAR/UTC_start	UTC seconds since 00:00 Z of the first profile (seconds)
CloudSat/GEOPROF-LIDAR/LayerTop	Height of layer top (m)
CloudSat/GEOPROF-LIDAR/FlagBase	Flag of layer base ()
CloudSat/GEOPROF-LIDAR/Data_status	Data status flags (--)
CloudSat/CLDCLASS/cloud_scenario	Cloud scenario (none)
CloudSat/CLDCLASS/DEM_elevation	Digital Elevation Map (meters)
CloudSat/CLDCLASS/Data_targetID	CPR bus orientation (target ID) (--)
CloudSat/CLDCLASS/nbin:2B-CLDCLASS	
CloudSat/CLDCLASS/nray:2B-CLDCLASS	
CloudSat/CLDCLASS/Longitude	Spacecraft Longitude (degrees)
CloudSat/CLDCLASS/Height	Height of range bin in Reflectivity/Cloud Mask above reference surface (~ mean sea level). (m)
CloudSat/CLDCLASS/Data_quality	Data Quality (--)
CloudSat/CLDCLASS/Vertical_binsize	(m)
CloudSat/CLDCLASS/Latitude	Spacecraft Latitude (degrees)
CloudSat/CLDCLASS/UTC_start	UTC seconds since 00:00 Z of the first profile (seconds)
CloudSat/CLDCLASS/Data_status	Data status flags (--)

The following table lists the variables in the AIRSM_CPR_MAT (aggregate AMSU file) data type:

Variable name	**Long name (units)**
AIRS/RetStd/CO_VMR_eff_err	
AIRS/RetStd/emisIRStdErr	
AIRS/RetStd/TSurfAirErr	
AIRS/RetStd/Qual_Cloud_OLR	
AIRS/RetStd/CH4_verticality	
AIRS/RetStd/H2O_verticality	
AIRS/RetStd/totO3Std	
AIRS/RetStd/TCldTopStdErr	
AIRS/RetStd/glintlat	
AIRS/RetStd/nSurfStd	
AIRS/RetStd/Longitude	
AIRS/RetStd/PBest	
AIRS/RetStd/nStd_mid_top_bndry	
AIRS/RetStd/CH4_total_column	
AIRS/RetStd/CO_total_column	
AIRS/RetStd/TSurfStdErr	
AIRS/RetStd/Qual_H2O	
AIRS/RetStd/totH2OStd	
AIRS/RetStd/Qual_clrolr	
AIRS/RetStd/TAirMWOnlyStd	
AIRS/RetStd/GP_Height	

AIRS/RetStd/olr	
AIRS/RetStd/Qual_Temp_Profile_Bot	
AIRS/RetStd/H2OMMRSat	
AIRS/RetStd/clrolr	
AIRS/RetStd/RetQAFlag	
AIRS/RetStd/Cloud_Resid_Ratio	
AIRS/RetStd/TSurfStd	
AIRS/RetStd/solazi	
AIRS/RetStd/Qual_CO	
AIRS/RetStd/numCloud	
AIRS/RetStd/Qual_Temp_Profile_Top	
AIRS/RetStd/Qual_Temp_Profile_Mid	
AIRS/RetStd/PCldTopStd	
AIRS/RetStd/clrolr_err	
AIRS/RetStd/TotCld_4_CCfinal	
AIRS/RetStd/landFrac_err	
AIRS/RetStd/PCldTopStdErr	
AIRS/RetStd/PGood	
AIRS/RetStd/TCldTopStd	
AIRS/RetStd/totCldH2OStdErr	
AIRS/RetStd/olr_err	
AIRS/RetStd/PSurfStd	
AIRS/RetStd/totH2OStdErr	
AIRS/RetStd/landFrac	
AIRS/RetStd/CO_dof	
AIRS/RetStd/solzen	
AIRS/RetStd/nStd_bot_mid_bndry	
AIRS/RetStd/PTropopause	
AIRS/RetStd/GP_Tropopause	
AIRS/RetStd/CO_VMR_eff	
AIRS/RetStd/CO_eff_press	
AIRS/RetStd/totO3StdErr	
AIRS/RetStd/TAirStdErr	
AIRS/RetStd/TAirStd	
AIRS/RetStd/H2OMMRSat_liquid	
AIRS/RetStd/O3VMRStdErr	
AIRS/RetStd/Press_mid_top_bndry	
AIRS/RetStd/Time	
AIRS/RetStd/totCldH2OStd	
AIRS/RetStd/satzen	
AIRS/RetStd/nGoodStd	

AIRS/RetStd/nBestStd	
AIRS/RetStd/TSurfAir	
AIRS/RetStd/O3VMRStd	
AIRS/RetStd/CO_verticality	
AIRS/RetStd/H2OMMRStd	
AIRS/RetStd/Latitude	
AIRS/RetStd/totH2OMWOnlyStd	
AIRS/RetStd/H2OMMRStdErr	
AIRS/RetStd/Press_bot_mid_bndry	
AIRS/RetStd/O3_verticality	
AIRS/RetStd/num_clear_spectral_indicator	
AIRS/RetStd/satazi	
AIRS/RetStd/emisIRStd	
AIRS/RetStd/freqEmis	
AIRS/RetStd/glintlon	
AIRS/RetStd/numHingeSurf	
AIRS/RetStd/T_Tropopause	
AIRS/RetStd/retrieval_type	
AIRS/RetSup/lwCDSup	
AIRS/RetSup/CH4CDSupErr	
AIRS/RetSup/emisIRStdErr	
AIRS/RetSup/H2OCDMWOnly	
AIRS/RetSup/TAirMWOnly	
AIRS/RetSup/Effective_Solar_Reflectance	
AIRS/RetSup/H2OCDSup	
AIRS/RetSup/O3CDSup	
AIRS/RetSup/freqEmis	
AIRS/RetSup/pressSupp	
AIRS/RetSup/H2OCDSupErr	
AIRS/RetSup/COCDSupErr	
AIRS/RetSup/TAirSup	
AIRS/RetSup/TAirSupErr	
AIRS/RetSup/COCDSup	
AIRS/RetSup/CH4CDSup	
AIRS/RetSup/emisIRStd	
AIRS/RetSup/lwCDSupErr	
CloudSat/GEOPROF/nray:2B-GEOPROF	
CloudSat/GEOPROF/nbin:2B-GEOPROF	
CloudSat/GEOPROF/Radar_Reflectivity	Radar Reflectivity Factor (dBZe)
CloudSat/GEOPROF/MODIS_scene_var	MODIS scene variability ()
CloudSat/GEOPROF/Sigma-Zero	Sigma-Zero (dB*100)

CloudSat/GEOPROF/MODIS_cloud_flag	MOD35_bit_2and3_cloud_flag (None)
CloudSat/GEOPROF/MODIS_scene_char	MODIS scene characterizations ()
CloudSat/GEOPROF/Longitude	Spacecraft Longitude (degrees)
CloudSat/GEOPROF/Height	Height of range bin in Reflectivity/Cloud Mask above reference surface (~ mean sea level). (m)
CloudSat/GEOPROF/Clutter_reduction_flag	Clutter_reduction_flag ()
CloudSat/GEOPROF/Profile_time	Seconds since the start of the granule. (seconds)
CloudSat/GEOPROF/CPR_Cloud_mask	CPR Cloud Mask ()
CloudSat/GEOPROF/Data_quality	Data Quality (--)
CloudSat/GEOPROF/MODIS_Cloud_Fraction	MODIS 250m Cloud Fraction ()
CloudSat/GEOPROF/Latitude	Spacecraft Latitude (degrees)
CloudSat/GEOPROF/Pitch_offset	Nominal satellite pitch angle offset from nadir (degrees)
CloudSat/GEOPROF/UTC_start	UTC seconds since 00:00 Z of the first profile (seconds)
CloudSat/GEOPROF/Navigation_land_sea_flag	Land Sea Flag (--)
CloudSat/GEOPROF/SurfaceHeightBin_fraction	SurfaceHeightBin_fraction (none)
CloudSat/GEOPROF/Data_status	Data status flags (--)
CloudSat/GEOPROF/SurfaceHeightBin	SurfaceHeightBin_fraction Location of Surface Bin as determined by 1B CPR algorithm. The value here is shifted (as Height). (none)
CloudSat/GEOPROF-LIDAR/UncertaintyCF	Uncertainty of Cloud Fraction ()
CloudSat/GEOPROF-LIDAR/LayerBase	Height of Layer Base (m)
CloudSat/GEOPROF-LIDAR/DEM_elevation	Digital Elevation Map (meters)
CloudSat/GEOPROF-LIDAR/nbin:2B-GEOPROF-LIDAR	
CloudSat/GEOPROF-LIDAR/Data_targetID	CPR bus orientation (target ID) (--)
CloudSat/GEOPROF-LIDAR/ncloud:2B-GEOPROF-LIDAR	
CloudSat/GEOPROF-LIDAR/Longitude	Spacecraft Longitude (degrees)
CloudSat/GEOPROF-LIDAR/Height	Height of range bin in Reflectivity/Cloud Mask above reference surface (~ mean sea level). (m)
CloudSat/GEOPROF-LIDAR/FlagTop	Flag of layer top ()
CloudSat/GEOPROF-LIDAR/Latitude	Spacecraft Latitude (degrees)
CloudSat/GEOPROF-LIDAR/CloudLayers	Number of hydrometeor layers ()
CloudSat/GEOPROF-LIDAR/Data_quality	Data Quality (--)
CloudSat/GEOPROF-LIDAR/Vertical_binsize	(m)
CloudSat/GEOPROF-LIDAR/CloudFraction	Cloud Fraction ()
CloudSat/GEOPROF-LIDAR/nray:2B-GEOPROF-LIDAR	
CloudSat/GEOPROF-LIDAR/UTC_start	UTC seconds since 00:00 Z of the first profile (seconds)
CloudSat/GEOPROF-LIDAR/LayerTop	Height of layer top (m)
CloudSat/GEOPROF-LIDAR/FlagBase	Flag of layer base ()
CloudSat/GEOPROF-LIDAR/Data_status	Data status flags (--)
CloudSat/CLDCLASS/cloud_scenario	Cloud scenario (none)
CloudSat/CLDCLASS/DEM_elevation	Digital Elevation Map (meters)
CloudSat/CLDCLASS/Data_targetID	CPR bus orientation (target ID) (--)
CloudSat/CLDCLASS/nbin:2B-CLDCLASS	

CloudSat/CLDCLASS/nray:2B-CLDCLASS	
CloudSat/CLDCLASS/Longitude	Spacecraft Longitude (degrees)
CloudSat/CLDCLASS/Height	Height of range bin in Reflectivity/Cloud Mask above reference surface (~ mean sea level). (m)
CloudSat/CLDCLASS/Data_quality	Data Quality (--)
CloudSat/CLDCLASS/Vertical_binsize	(m)
CloudSat/CLDCLASS/Latitude	Spacecraft Latitude (degrees)
CloudSat/CLDCLASS/UTC_start	UTC seconds since 00:00 Z of the first profile (seconds)
CloudSat/CLDCLASS/Data_status	Data status flags (--)

2.3.1 Science Area 1: Atmospheric Moist Processes and Trends

The AIRS variables in the table below are particularly relevant to studies of atmospheric moist thermodynamics, including trending. The Level 3 products being created for this MEaSUREs project are based mostly on these variables. This table will be expanded to include MLS temperature and water vapor profiles and AMSR-E total precipitable water vapor; the L3 data will include them. Quantities in bold are fundamental observed quantities.

2.3.2 Science Area 2: Atmospheric Water Cycle

The comments immediately above also hold for studies of the atmospheric water cycle.

Variable name	Variable Descriptor
AIRS/RetStd/CldFrcStd	Retrieved quantity
AIRS/RetStd/TSurfAirErr	Error estimate on retrieved quantity
AIRS/RetStd/H2O_verticality	Retrieved quantity
AIRS/RetStd/TCldTopStdErr	Error estimate on retrieved quantity
AIRS/RetStd/nSurfStd	Retrieved quantity
AIRS/RetStd/Longitude	Independent geospatial coordinate
AIRS/RetStd/PBest	Quality flag or parameter
AIRS/RetStd/nStd_mid_top_bndry	Quality flag or parameter
AIRS/RetStd/TSurfStdErr	Error estimate on retrieved quantity
AIRS/RetStd/Qual_H2O	Quality flag or parameter
AIRS/RetStd/totH2OStd	**Retrieved total water vapor**
AIRS/RetStd/TAirMWOnlyStd	Retrieved quantity
AIRS/RetStd/GP_Height	Retrieved quantity
AIRS/RetStd/olr	Retrieved quantity
AIRS/RetStd/Qual_Temp_Profile_Bot	Quality flag or parameter
AIRS/RetStd/H2OMMRSat	Retrieved quantity
AIRS/RetStd/clrolr	Retrieved quantity
AIRS/RetStd/TSurfStd	Retrieved quantity
AIRS/RetStd/solazi	Independent geospatial coordinate

AIRS/RetStd/numCloud	Retrieved quantity
AIRS/RetStd/Qual_Temp_Profile_Top	Quality flag or parameter
AIRS/RetStd/Qual_Temp_Profile_Mid	Quality flag or parameter
AIRS/RetStd/PCldTopStd	Retrieved quantity
AIRS/RetStd/clrolr_err	Error estimate on retrieved quantity
AIRS/RetStd/landFrac_err	Error estimate on retrieved quantity
AIRS/RetStd/PCldTopStdErr	Error estimate on retrieved quantity
AIRS/RetStd/PGood	Quality flag or parameter
AIRS/RetStd/TCldTopStd	Retrieved quantity
AIRS/RetStd/olr_err	Error estimate on retrieved quantity
AIRS/RetStd/PSurfStd	Provided by model forecast
AIRS/RetStd/totH2OStdErr	Error estimate on retrieved quantity
AIRS/RetStd/landFrac	Retrieved quantity / Independent geospatial coordinate
AIRS/RetStd/solzen	Independent geospatial coordinate
AIRS/RetStd/nStd_bot_mid_bndry	Quality flag or parameter
AIRS/RetStd/PTropopause	Retrieved quantity
AIRS/RetStd/GP_Tropopause	Retrieved quantity
AIRS/RetStd/TAirStdErr	Error estimate on retrieved quantity
AIRS/RetStd/TAirStd	**Retrieved atmospheric temperature**
AIRS/RetStd/H2OMMRSat_liquid	Retrieved quantity
AIRS/RetStd/Press_mid_top_bndry	Quality flag or parameter
AIRS/RetStd/Time	Independent geospatial coordinate
AIRS/RetStd/satzen	Independent geospatial coordinate
AIRS/RetStd/nGoodStd	Quality flag or parameter
AIRS/RetStd/nBestStd	Quality flag or parameter
AIRS/RetStd/TSurfAir	**Retrieved surface air temperature**
AIRS/RetStd/H2OMMRStd	**Retrieved water vapor profile**
AIRS/RetStd/Latitude	Independent geospatial coordinate
AIRS/RetStd/totH2OMWOnlyStd	**Total water vapor retrieved from microwave observations**
AIRS/RetStd/H2OMMRStdErr	Error estimate on retrieved quantity
AIRS/RetStd/Press_bot_mid_bndry	Quality flag or parameter
AIRS/RetStd/satazi	Independent geospatial coordinate
AIRS/RetStd/glintlon	Independent geospatial coordinate
AIRS/RetStd/T_Tropopause	Retrieved quantity
AIRS/RetSup/TAirMWOnly	Retrieved quantity
AIRS/RetSup/H2OCDSup	**Retrieved water vapor profile at high vertical resolution**
AIRS/RetSup/pressSupp	Independent geospatial coordinate
AIRS/RetSup/H2OCDSupErr	Error estimate on retrieved quantity
AIRS/RetSup/TAirSup	**Retrieved temperature profiles at high vertical resolution**
AIRS/RetSup/TAirSupErr	Error estimate on retrieved quantity

3.0 Data Contents

3.1 Dimensions

3.1.1 AIRS_CPR_IND (Aggregate AIRS File)

Name	Description
airs_idx	Matchup index
O3Func	num_O3_Func from AIRS RetStd Product
COFunc	num_CO_Func from AIRS RetStd Product
StdPressureLay	pressStd from AIRS RetStd Product
H2OPressureLay	pressH2O from AIRS RetStd Product
Cloud	numCloud from AIRS RetStd Product
H2OFunc	num_H2O_Func from AIRS RetStd Product
CH4Func	num_CH4_Func from AIRS RetStd Product
StdPressureLev	pressStd from AIRS RetStd Product
HingeSurf	HingeSurf from AIRS L1B Radiances Product
Channel:L1B_AIRS_Science	Channel:L1B_AIRS_Science from AIRS L1B Radiances Product
cs_idx	CloudSat footprint matchup index
cs_col	1
cs_nbin	nbin:2B-GEOPROF from CloudSat GEOPROF Product
cs_ncloud	ncloud:2B-GEOPROF-LIDAR from CloudSat GEOPROF-LIDAR Product

3.1.2 AIRSM_CPR_MAT (Aggregate AMSU File)

Name	Description
amsu_idx	Matchup index
amsu_track_idx	45
O3Func	num_O3_Func from AIRS RetStd Product
COFunc	num_CO_Func from AIRS RetStd Product
StdPressureLay	pressStd from AIRS RetStd Product
H2OPressureLay	pressH2O from AIRS RetStd Product
Cloud	numCloud from AIRS RetStd Product
H2OFunc	num_H2O_Func from AIRS RetStd Product
CH4Func	num_CH4_Func from AIRS RetStd Product
StdPressureLev	pressStd from AIRS RetStd Product
HingeSurf	HingeSurf from AIRS L1B Radiances Product
cs_idx	CloudSat footprint matchup index
cs_col	1
cs_nbin	nbin:2B-GEOPROF from CloudSat GEOPROF Product
cs_ncloud	ncloud:2B-GEOPROF-LIDAR from CloudSat GEOPROF-LIDAR Product

3.2 Global Attributes

Global metadata is also stored in the files. Some metadata are required by standard conventions, some are present to meet data provenance requirements and others as a convenience to users of the WVCC AIRS-CloudSat merged dataset. A summary of global attributes present in all netcdf files is shown in Table 3.3.

Global Attribute	Type	Description
title	String	Specifies AIRS granule used for the matchup
PRODUCTIONDATE	String	Specifies production time in the format YYYYMMDDHHSS
CloudSatGranules	String	CloudSat granule(s) that matched up to AIRS granule
RANGEBEGINNINGDATE	String	Start date of AIRS granule
RANGEBEGINNINGTIME	String	Start time of AIRS granule
RANGEENDINGDATE	String	Ending date of AIRS granule
RANGEENDINGTIME	String	Ending date of AIRS granule
NORTHBOUNDINGCOORDINATE	Float	North bounding coordinate of AIRS granule
SOUTHBOUNDINGCOORDINATE	Float	South bounding coordinate of AIRS granule
EASTBOUNDINGCOORDINATE	Float	East bounding coordinate of AIRS granule
WESTBOUNDINGCOORDINATE	Float	West bounding coordinate of AIRS granule

Table 3.3: Global metadata attributes associated with each netcdf file

A list of key metadata fields can be found in Table 3.4 - Key Metadata Items. Not listed here are variable attributes from the source dataset granule that were carried over. Global attributes in a netcdf file can be viewed with *ncdump* software:
ncdump –h -c <WVCC AIRS-CloudSat netcdf file>

Name	Type	Description
missing |_FillValue	Float|Int	Floating-point value used to identify missing data. Will normally be set to -9999.. Required by CF.
long_name	String	Long name
units	String	Units

Table 3.4: Key Metadata Items

3.3 Products/Parameters

Refer to section 2.3 for product parameters.

4.0 Options for Reading the Data

4.1 Command Line Utilities

ncdump

The ncdump tool can be used as a simple browser for NetCDF data files, to display the dimension names and sizes; variable names, types, and shapes; attribute names and values; and optionally, the values of data for all variables or selected variables in a NetCDF file. The most common use of ncdump is with the –h option, in which only the header information is displayed.

ncdump [-c|-h] [-v ...] [[-b|-f] [c|f]] [-l len] [-n name] [-d n[,n]] filename
Options/Arguments:
[-c] Coordinate variable data and header information
[-h] Header information only, no data
[-v var1[,...]] Data for variable(s) <var1>,... only data
[-f [c|f]] Full annotations for C or Fortran indices in data
[-l len] Line length maximum in data section (default 80)
[-n name] Name for netCDF (default derived from file name)
[-d n[,n]] Approximate floating-point values with less precision filename File name of input netCDF file

Note: the ncdump tool will only display variables whose ranks are great than 1. In other words, you will not see one dimensional vectors such as *satheight* using this tool.
The ncdump program can be found in bin directory of the HDF installation area. Consult your local computer system administrator for the specifics.

4.2 Tools/Programming

Here we provide some python code snippets.

4.2.1 Read Variables

```
import netCDF4

ncFile = 'matched-airs.aqua_cloudsat-v3.1-2006.10.07.240_airs.nc'

f = netCDF4.Dataset(ncFile)

# print all variables in the file
datasets =  f.groups.keys()
for d in datasets:
   dataset = f.groups[d]
   products = dataset.groups.keys()
   for p in products:
      product = dataset.groups[p]
      vars = product.variables.keys()
      for v in vars:
         print d, p, v

# pull out some variables
cloud_scen = f.groups['CloudSat'].groups['CLDCLASS'].variables['cloud_scenario'][:]
heigth = f.groups['CloudSat'].groups['GEOPROF'].variables['Height'][:]
csLat = f.groups['CloudSat'].groups['GEOPROF'].variables['Latitude'][:]
radiances = f.groups['AIRS'].groups['Radiances'].variables['radiances'][:]

f.close()
```

4.2.2 Plot Cloud Scene

```
import os, sys, netCDF4
import numpy as N
from mpl_toolkits.basemap import Basemap
import matplotlib.pyplot as plt
import matplotlib.cm as cm
from pylab import linspace
from scipy import interpolate
from matplotlib.colors import LinearSegmentedColormap

'''
Run from command-line like this:
$ python plotCloudScene.py matched-airs.aqua_cloudsat-v3.1-2006.10.07.240_airs.nc test.png
$ display test.png
'''

def cmap_discretize(cmap, n):

    """Return a discrete colormap from the continuous colormap cmap.

        cmap: colormap instance, eg. cm.jet.
        n: number of colors.

    Example
        x = resize(arange(100), (5,100))
        djet = cmap_discretize(cm.jet, 5)
        imshow(x, cmap=djet)
    """

    cdict = cmap._segmentdata.copy()
    # n colors
    colors_i = linspace(0,1.,n)
    # n+1 indices
    indices = linspace(0,1.,n+1)
    for key in ('red','green','blue'):
        # Find the n colors
        D = N.array(cdict[key])
        I = interpolate.interp1d(D[:,0], D[:,1])
        colors = I(colors_i)
        # Place these colors at the correct indices.
        A = N.zeros((n+1,3), float)
        A[:,0] = indices
        A[1:,1] = colors
        A[:-1,2] = colors
        # Create a tuple for the dictionary.
        L = []
        for l in A:
            L.append(tuple(l))
        cdict[key] = tuple(L)
    # Return colormap object.
    return LinearSegmentedColormap('colormap',cdict,1024)

#set input and output files
ncFile = sys.argv[1]
plotFile = sys.argv[2]

#continued on next page
```

```
#continued from previous  page

#read in vars
f = netCDF4.Dataset(ncFile)
fig = plt.figure()
fig.clf()
cloud_scen = f.groups['CloudSat'].groups['CLDCLASS'].variables['cloud_scenario'][:]
height = f.groups['CloudSat'].groups['GEOPROF'].variables['Height'][:]
csLat = f.groups['CloudSat'].groups['GEOPROF'].variables['Latitude'][:]
radiances = f.groups['AIRS'].groups['Radiances'].variables['radiances'][:]
l1bLat = f.groups['AIRS'].groups['Radiances'].variables['Latitude'][:]

#get cloudsat latitude values range
csLat_range = list(set(csLat.flatten().tolist()))
csLat_range.sort()

#build cloudsat lat array with same shape as cloud_scenario
newCsLat = N.zeros(cloud_scen.shape)
for i in range(newCsLat.shape[2]): newCsLat[:,:,i] = csLat

#get cloud type bits (bits 1-4, little-endian)
cloud_scen_shift = N.right_shift(N.array(cloud_scen), 1) & int('1111', 2)

cloudTypes = {
   '0000': 'clear',
   '0001': 'Ci',
   '0010': 'As',
   '0011': 'Ac',
   '0100': 'St',
   '0101': 'Sc',
   '0110': 'Cu',
   '0111': 'Ns',
   '1000': 'DC'
}

#plot
sp = fig.add_subplot(111)
csPlot = sp.scatter(newCsLat.flatten(), height.flatten(),
                c=cloud_scen_shift.flatten(),
                vmin=int('0000', 2),
                vmax=int('1000', 2),
                edgecolors='none',
                cmap=cmap_discretize(cm.gist_ncar_r, 9))

#set x(lat) and y(height) limits
if csLat.max() > 90: sp.set_xlim(csLat.min(), csLat_range[-2])
else: sp.set_xlim(csLat.min(), csLat.max())
sp.set_ylim(0, height.max())

#set plot attrs
sp.set_xlabel('CloudSat Latitude')
sp.set_ylabel('CloudSat Height (m)')
plt.title("Cloud Scene")
cb = plt.colorbar(csPlot, ticks=range(9)) #set ticks
cb.ax.set_yticklabels([cloudTypes[N.binary_repr(i, 4)] for i in range(9)]) #set tick labels

#write file
fig.savefig(plotFile)
plt.close(fig)
```

A plot similar to the following will be generated:

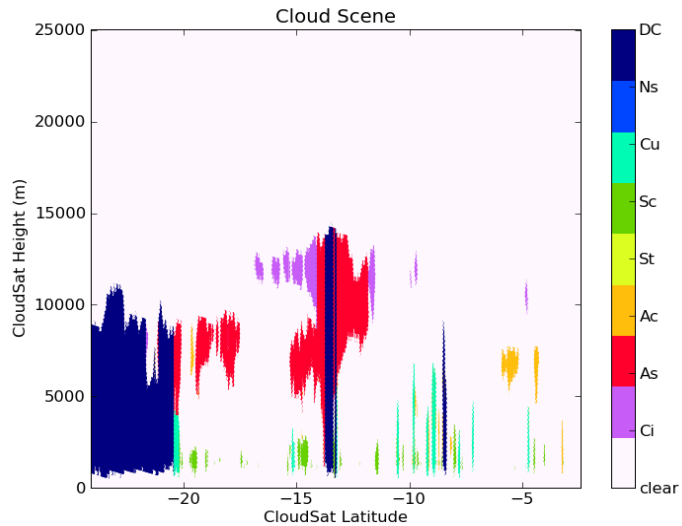

Figure 4.1: Cloud Scene

5.0 Data Services

GES DISC provides basic temporal and advanced (event) searches through its search and download engine, Mirador:
http://mirador.gsfc.nasa.gov/

Mirador offers various download options that suit users with different preferences and different levels of technical skills. Users can start from a point where they don't know anything about these particular data, its location, size, format, etc., and quickly find what they need by just providing relevant keywords, like "Cloud Classification". As the project progresses, more services will be added that will allow options for subsetting, format conversion, and previews using open source software such as OPeNDAP and Panoply.

If you need assistance or wish to report a problem:
Email: gsfc-help-disc@lists.nasa.gov
Voice: 301-614-5224
Fax: 301-614-5268
Address:
Goddard Earth Sciences Data and Information Services Center NASA Goddard Space Flight Center Code 610.2 Greenbelt, MD 20771 USA

6.0 More Information

All WVCC data types are published to the Global Change Master Directory:

http://gcmd.nasa.gov

This is a centralized depository of climate data information that is catalogued by popular keywords, which facilitate data discovery. Since the Directory is visited by a large number of people working on a broad range of research topics, it is an excellent forum to popularize data collections. It also serves as source of data type information for Mirador.

7.0 Acknowledgements

The creators for WVCC are:

Eric Fetzer, Brian Wilson, and Gerald Manipon.

References

AIRS Version 4.0 Processing Files Description, JPL D-38428, June July 2007:
http://disc.sci.gsfc.nasa.gov/AIRS/documentation

CloudSat Standard Data Products Handbook, May 18, 2006:
http://www.cloudsat.cira.colostate.edu/dataHome.php

Level 2 Cloud Scenario Classification Product Process Description and Interface Control Document, Version: 4.0, March 1, 2005.

NetCDF4: http://www.unidata.ucar.edu/software/netcdf/

For information on the Python programming language, consult the documentation:
http://www.python.org.