AIRS Version 5 Release
Level 2 Standard Product QuickStart

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Submit Questions to:
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Introduction

The purpose of the document is to give users of the V5 Level 2 Standard Products a quick summary of the key information they require to properly use the products in their research. This is not a complete characterization of the Level 2 Standard Products.

Each class of Level 2 Standard Product is presented. A user pursuing research on the distribution and transport of carbon monoxide will find much of interest in that section and can ignore most of the other sections. **All users, however, must read the sections describing the *Standard Temperature Product* and the *Standard Moisture Product*. Information appearing in these two sections is critically important to proper understanding and use of the other standard products in research.**

Sometimes it is necessary to allude to the Level 2 Support Products in the description of the Level 2 Standard Products. The Support Products are beyond the scope of this document. Suffice to say that they are not recommended to the casual user. The temperature and moisture profiles contained within them are of higher vertical resolution (100 levels), but are not independent. Their major utility is for forward calculation of radiances via the AIRS RTA, beta testing future products and for investigating the operation of the retrieval algorithm. Values appearing in the Support Product can be intermediate calculation resulting from an interrupted retrieval. They might look physical, but they are not. In the words describing unknowns on ancient maritime maps: “Here there be dragons.”

We have avoided referring to the names of the product files or their “shortnames” in this document. However, there exist two versions of the Level 2 Standard Product files before February 5, 2003. On that date, the Humidity Sounder for Brazil (HSB) failed. Our retrieval algorithm was adjusted to allow operation with and without ingesting HSB radiances. Retrievals for the period before February 5, 2003 are carried out with and without HSB. The AIRS Level 2 Standard Product granules resulting from including HSB radiances have shortname “AIRH2RET” and their file names incorporate this character string. Granules resulting from not ingesting HSB radiances have shortname “AIRX2RET” and their file names incorporate this character string. This latter set carries through after February 5, 2003 to the current date and is the bulk of the AIRS Level 2 product. It is produced for the period before HSB failed so that a consistent product exists for the entire period of the operation of AIRS. The Level 2 Support Product similarly has two versions: “AIRH2SUP” and “AIRX2SUP”. The Level 2 Cloud Cleared Product also has two versions: “AIRH2CCF” and “AIRX2CCF”.

In this documentation, names in bold are fields in the AIRS product files.

Example Level 2 Product File Names

The following examples are Level 2 product files for granule 131 for the date, December 31, 2009. AIRS-Only products will only be release in the event of a failure of AMSU.

Standard Product processed using AIRS and AMSU radiances:
Name: AIRS.2009.12.03.131.L2.RetStd.v5.0.14.0.G2002123120634.hdf
Shortname: AIRX2RET

Standard Product processed using AIRS, AMSU and HSB radiances:
Name: AIRS.2009.12.03.131.L2.RetStd_H.v5.0.14.0.G2002123120634.hdf
Shorthame: AIRH2RET

Standard Product processed using only AIRS radiances:
Name: AIRS.2009.12.03.131.L2.RetStd_IR.v5.0.14.0.G2002123120634.hdf
Shortname: AIRS2RET

Support Product processed using AIRS and AMSU radiances:
Name: AIRS.2009.12.03.131.L2.RetSup.v5.0.14.0.G2002123120634.hdf
Shortname: AIRX2SUP

Support Product processed using AIRS, AMSU and HSB radiances:
Name: AIRS.2009.12.03.131.L2.RetSup_H.v5.0.14.0.G2002123120634.hdf
Shortname: AIRH2SUP

Standard Product processed using only AIRS radiances:
Name: AIRS.2009.12.03.131.L2.RetSup_IR.v5.0.14.0.G2002123120634.hdf
Shortname: AIRS2SUP

AIRS Cloud-Cleared Radiances for the 3 different processing options:

Product File Name	Shortname
AIRS.2009.12.03.131.L2.CC.v5.0.14.0.G2002123120634.hdf	AIRI2CCF
AIRS.2009.12.03.131.L2.CC_H.v5.0.14.0.G2002123120634.hdf	AIRH2CCF
AIRS.2009.12.03.131.L2.CC_IR.v5.0.14.0.G2002123120634.hdf	AIRS2CCF

Microwave-Only Standard Products

The Microwave-Only (MW-Only) standard products are retrieved by the MW retrieval stage of the AIRS algorithm. No IR data are used to retrieve these products. All other products described later in this document are retrieved employing the combined IR/MW retrieval stages of the AIRS algorithm, providing greater vertical resolution of temperature and water vapor fields, improved surface emissivity and retrievals of atmospheric constituents. The field-of-view (FOV) is that of the Advanced Microwave Sounding Unit (AMSU), which is 40.5 km at nadir.

Field Name	Dimension per FOV	Description
PSurfStd	1	Surface pressure, interpolated from the NCEP GFS forecasts and local DEM topography (mb)
pressStd	StdPressureLev=28	Pressure levels upon which temperature profiles and geopotential heights are reported (mb)
nSurfStd	1	Index of lowest altitude pressStd element which is above the surface (1-based) (unitless)
TAirMWOnlyStd	StdPressureLev=28	Retrieved Atmospheric Temperature Profile. Value below index nSurfStd may be an unphysical extrapolated value for a pressure level below the surface (K)
TAirMWOnlyErr	StdPressureLev=28	Error estimate for atmospheric temperature profile, but it is in the L2 Support Product (K)
GP_Height_MWOnly	StdPressureLev=28	Geopotential height (above mean sea level) for each pressStd (m)
MWSurfClass	1	Surface class information (unitless)

Field Name	Dimension per FOV	Description
sfcTbMWStd	MWHingeSurf=7	Microwave surface brightness. Includes only emitted radiance, i.e. no reflected radiance, at the 7 MW frequencies stored in attribute MWHingeSurfFreqGHz (K)
EmisMWStd	MWHingeSurf=7	Spectral MW emissivity at the 7 MW frequencies (unitless)
EmisMWStdErr	MWHingeSurf=7	Error estimate (unitless)
totH2OMWOnlyStd	1	Total precipitable water vapor (kg/m^2)
totCldH2OStd	1	Total cloud liquid water (kg/m^2)
totCldH2OStdErr	1	Error estimate (kg/m^2)

Description

The 28 Level 2 Standard pressure levels (**pressStd**) are arranged in order of decreasing pressure. The document, **V5_L2_Standard_Pressure_Levels.pdf**, provides a table of their values. The highest altitude pressure level is pressStd(28) = 0.1 mb. The index of the lowest altitude pressure level for which a reported **TAirMWOnlyStd** is valid is **nSurfStd**, which may be 1, 2, …, 15 depending upon topography. The surface pressure, interpolated from the NCEP GFS forecast and the local DEM topography, is **PSurfStd**.

totcldH2OStd is the integral of the cloud liquid water profile. The estimated error, **totCldH2OStdErr**, is set according to surface type with values ranging from 0.02 kg/m^2 to 0.15 kg/m^2 if **Qual_MW_Only_H2O** = 0 or 1. In the event that Qual_MW_Only_H2O = 2, it is set to 1.00 kg/m^2.

MWSurfClass is produced by a classification algorithm employing AMSU-A data and the **landFrac** parameter (i.e., the fraction of the surface of the FOV covered by land). The possible values are:

-1 = unknown (not attempted)

0 = coastline (liquid water covers 50% to 99% of FOV)

1 = land (liquid water covers less than 50% of FOV)

2 = ocean (liquid water covers more than 99% of FOV)

3 = sea ice (high MW emissivity)

4 = sea ice (low MW emissivity)

5 = snow (higher-frequency MW scattering)

6 = glacier/snow (very low-frequency MW scattering)

7 = snow (lower-frequency MW scattering)

The difference between **MWSurfClass** = 3 and 4, or among **MWSurfClass** = 5, 6, 7 is in the microwave signature of the ice and/or snow. There are complex physical reasons for the differences, including age. Users may collapse the **MWSurfClass** values present here into NOAA's AMSU-product classes by combining 3 and 4 for sea ice and 5, 6 and 7 for land snow/ice.

sfcTbMWStd is the surface brightness temperature retrieved at the seven frequencies: 23.8, 31.4, 50.3, 52.8, 89.0, 150.0, 183.31 GHz. **EmisMWStd** is derived as the ratio of **sfcTbMWStd** to an estimated MW-Only surface skin temperature. The estimated error, **EmisMWStdErr**, is frequency dependent and varies between 0.015 and 0.034, based on simulations. If the retrieved values are rejected, **EmisMWStdErr** values are set ≥ 1.0. The effective MW-Only surface skin temperature may be calculated by dividing an element of **EmisMWStd** by the corresponding element of **EmisMWStd**, but we advise users doing so that the values resulting from this calculation are not supported and are not validated as a product.

Type of Product

All MW-Only standard product profiles are level quantities, which means that the values are reported at fixed pressure levels. This differs from layer quantities, which are reported on the fixed pressure levels but represent the layer bounded by the level on which they are reported and the next higher level (in altitude).

For more detail, see **V5_L2_Levels_Layers_Trapezoids.pdf** for a full discussion of level and layer quantities.

Quality Indicators

Qual_MW_Only_Temp_Tropo pertains to the part of the **TAirMWOnlyStd** profile at pressures equal to or greater than 201 hPa. It is set by examining the bits in **MW_ret_code** corresponding to tropospheric temperature channels to detect:

Excessive residuals
Excessive liquid water (> 0.5 kg/m^2)
Insufficient valid channels
Numerical error
Emissivity not within the interval [0,1] for any AMSU-A channel

If any of these five bits are set, then **Qual_MW_Only_Temp_Tropo** is set to 2; otherwise it is set to 0.

Qual_MW_Only_Temp_Strat pertains to the part of the**TAirMWOnlyStd** profile at pressures less than 201 hPa, It is set by examining the bits in **MW_ret_code** corresponding to stratospheric temperature channels to detect:

Excessive residuals
Insufficient valid channels
Numerical error

If any of these three bits are set, then **Qual_MW_Only_Temp_Strat** is set to 2; otherwise it is set to 0.

Thus, for these two quality indicators:

0 = associated profile segment accepted

2 = associated profile segment rejected, researchers should not use

Qual_MW_Only_H2O is the overall quality indicator for MW-Only moisture fields: **totH2OMWOnlyStd**, **totCldH2OStd**, and the column density profiles located in the L2 Support Product (**H2OCDMWOnly** and **lwCDSup**). The failure of HSB on February 5, 2003 degraded various moisture research products, and this quality factor is set in part by the availability of HSB data. It is set by examining the bits in **MW_ret_code** for channels affecting the moisture retrieval to detect:

Excessive residuals
Excessive liquid water (> 0.5 kg/m2)
Insufficient valid channels
Numerical error
Emissivity not within the interval [0,1] for any AMSU-A channel

If any of these five bits are set, then **Qual_MW_Only_H2O** is set to 2.

If the test on **MW_ret_code** yields no fault, an additional test is performed. If HSB data are present **Qual_MW_Only_H2O** is set to 0. If HSB data are not present and **MWSurfClass** = 0 or 2, **Qual_MW_Only_H2O** is set to 1 and it is set to 2 for all other surface types. Note that **Qual_MW_Only_H2O** = 1 constitutes an exception to the general rule of the quality indicator values, since it is the best level of quality that can be achieved when HSB data are not available.

The user should filter MW-Only moisture retrievals according to the value of **Qual_MW_Only_H2O** as follows:

0 = (HSB data used) use column totals and support product profiles

1 = (HSB data not used) use only the column totals

2 = moisture retrieval rejected, do not use

Caveats

Note that there are values for EmisMWStd and sfcTbMWStd for the 150 GHz and 183 GHz channels only if HSB data are available, otherwise the values will be set to -9999.0. The AIRS Level 2 Standard Product in which HSB data are available is the AIRH2RET version. The AIRX2RET version does not ingest HSB data.

All parameters that are level numbers, such as **nSurfStd**, are 1-based. Those who work in FORTRAN and MATLAB will be unaffected. However, those who work in C and IDL must take care when using nSurfStd and other parameters that are level numbers. The following two expressions yield the same value:

FORTRAN and MATLAB: **TAirMWOnlyStd**(**nSurfStd**)
C and IDL: **TAirMWOnlyStd**[**nsurfStd**-1]

The value of **TAirMWOnlyStd** at index **nSurfStd** (in FORTRAN and MATLAB) or index **nSurfStd**-1 (in C and IDL) may be an unphysical extrapolated value for a pressure level below the surface. The user must also compare **PSurfStd** to the associated **pressStd** element. If (for IDL) **PSurfStd** < **pressStd**[**nSurfStd**-1] then the level falls below the local surface and **TAirMWOnlyStd**[**nsurfStd**-1] is not physical.

Suggestions for Researchers

We caution users to avoid combining MW-only retrieval products with products retrieved via the combined IR/MW algorithm in your analyses. The two products are quite different in character.

Recommended Papers

N. Grody, F.Weng, and R. Ferraro, “Application of AMSU for obtaining hydrological parameters,” in Microwave Radiometry and Remote Sensing of the Earth’s Surface and Atmosphere, edited by P. Pampaloni and S. Paloscia, pp. 339–352, Brill Acad., Leiden, Netherlands (2000).

P. W. Rosenkranz, “Retrieval of temperature and moisture profiles from AMSU-A and AMSU-B measurements”, IEEE Trans. Geosci. Rem. Sens. v.39, pp.2429-2435 (2001).

P. W. Rosenkranz, “Rapid radiative transfer model for AMSU/HSB channels,” IEEE Trans. Geosci. Rem. Sens., v.41, pp.362-368 (2003).

P. W. Rosenkranz, “Cloud liquid-water profile retrieval algorithm and validation,” J. Geophys. Res., v.111, D09S08, doi:10.1029/2005JD005832 (2006).

P. W. Rosenkranz and C. D. Barnet, “Microwave radiative transfer model validation,” J. Geophys. Res., v.111, D09S07, doi:10.1029/2005JD006008 (2006).

Recommended Supplemental User Documentation

V5_L2_Standard_Pressure_Levels.pdf

V5_L2_Levels_Layers_Trapezoids.pdf

V5_L2_Quality_Control_and_Error_Estimation.pdf

V5_CalVal_Status_Summary.pdf

V5_Retrieval_Flow.pdf

AIRS Standard Temperature Product

Field Name	Dimension per FOV	Description
PSurfStd	1	Surface pressure, interpolated from the NCEP GFS forecasts and local DEM topography (mb)
pressStd	StdPressureLev=28	Pressure levels upon which TAIRStd profiles and geopotential heights are reported (mb)
nSurfStd	1	Index of lowest altitude pressStd element which is above the surface (1-based) (unitless)
TAirStd	numTempLayers=28	Retrieved Atmospheric Temperature Profile (K)
TAirStdErr	numTempLayers=28	Error estimate for TAIRStd (K)
Temp_Resid_Ratio	1	Internal retrieval quality indicator; residuals of temperature channels compared to predicted uncertainty (unitless)
TSurfAir	1	Retrieved Surface Air Temperature (K)
TSurfAirErr	1	Error Estimate for TSurfAir (K)
PTropopause	1	Pressure at tropopause (mb)
T_Tropopause	1	Temperature at tropopause (K)
GP_Tropopause	1	Geopotential height (above mean sea level) at tropopause (m)
GP_Height	StdPressureLev=28	Geopotential height (above mean sea level) for each pressStd (m)
GP_Surface	1	Geopotential height (above mean sea level) at surface (m)

Description

The AIRS standard temperature product is the result of the combined IR/MW retrieval. See the MW-Only product (above) for temperature products derived solely from the microwave data. The atmospheric temperature profile (**TAirStd**) is reported on the standard pressure levels (**pressStd**) that are above the altitude of the highest topography in the retrieval FOV.

The surface air temperature (**TSurfAir**) and **TAirStd** are obtained from the 100-level support product air temperature profile (**TAirSup**) using interpolation that is linear in the logarithm of the support pressure (**pressSup**).

Note that **TSurfAir** will equal **TAirStd**(**nSurfStd**) only if **pressStd**(**nSurfStd**) is equal to **PSurfStd**. This will seldom be the case.

The 28 Level 2 Standard pressure levels (**pressStd**) are arranged in order of decreasing pressure. The highest altitude pressure level is pressStd(28) = 0.1 mb. The index of the lowest altitude pressure level for which a reported **TAirStd** is valid is **nSurfStd**, which may be 1, 2, …, 15 depending upon topography. The surface pressure, interpolated from the NCEP GFS forecast and the local DEM topography, is **PSurfStd**.

PTropopause is determined by testing the lapse rate of the higher vertical resolution air temperature profile (**TAirSup**) against the WMO (1992) criteria:

> 1) The first tropopause (i.e., the conventional tropopause) is defined as the lowest level at which (a) the lapse rate decreases to 2 K/km or less, and (b) the average lapse rate from this level to any level within the next higher 2 km does not exceed 2 K/km.
>
> 2) If above the first tropopause the average lapse rate between any level and all higher levels within 1 km exceed 3 K/km, then a second tropopause is defined by the same criterion as under the statement above. This tropopause may be either within or above the 1 km layer.
>
> 3) A level otherwise satisfying the definition of tropopause, but occurring at an altitude below that of the 500 mb level will not be designated a tropopause unless it is the only level satisfying the definition and the average lapse rate fails to exceed 3 K/km over at least 1 km in any higher layer.

The V5 code evaluates the lapse rate by taking the derivative of the cubic spline interpolation of the Level 2 Support Product profiles of **TAirSup** versus **pressSup**. Between the 100 support levels, the lapse rate is linearly interpolated between values at the support levels to determine where condition (1a) is satisfied. Linearly interpolation is used rather than evaluating the derivative of the spline (a quadratic function) to filter oscillation from the interpolation. Average lapse rates to test against conditions (1b), (2), and (3) are evaluated in the same fashion, except that the averages are evaluated over the thickness obtained by approximating altitude thicknesses by the first term of the Taylor series expansion of altitude in temperature:

$$\Delta \,\text{Altitude} = \Delta \,\text{Pressure} \times \frac{\text{T}}{\text{T}_0}$$

T_Tropopause and **GP_Tropopause** are thus determined as well. In V4, the pressure was simply set to the nearest **pressSup** value. The values determined in V5 do not have this property. Instead, the V5 algorithm interpolates between the levels of the support profile in order to obtain a better estimate of the temperature minimum and a continuous range of pressure. However, the temperature profile is a mixture of regression and final retrieval and the regression has some scan angle dependence. Thus these quantities often show scan angle "striping" (i.e., the pressures preferentially assume particular values).

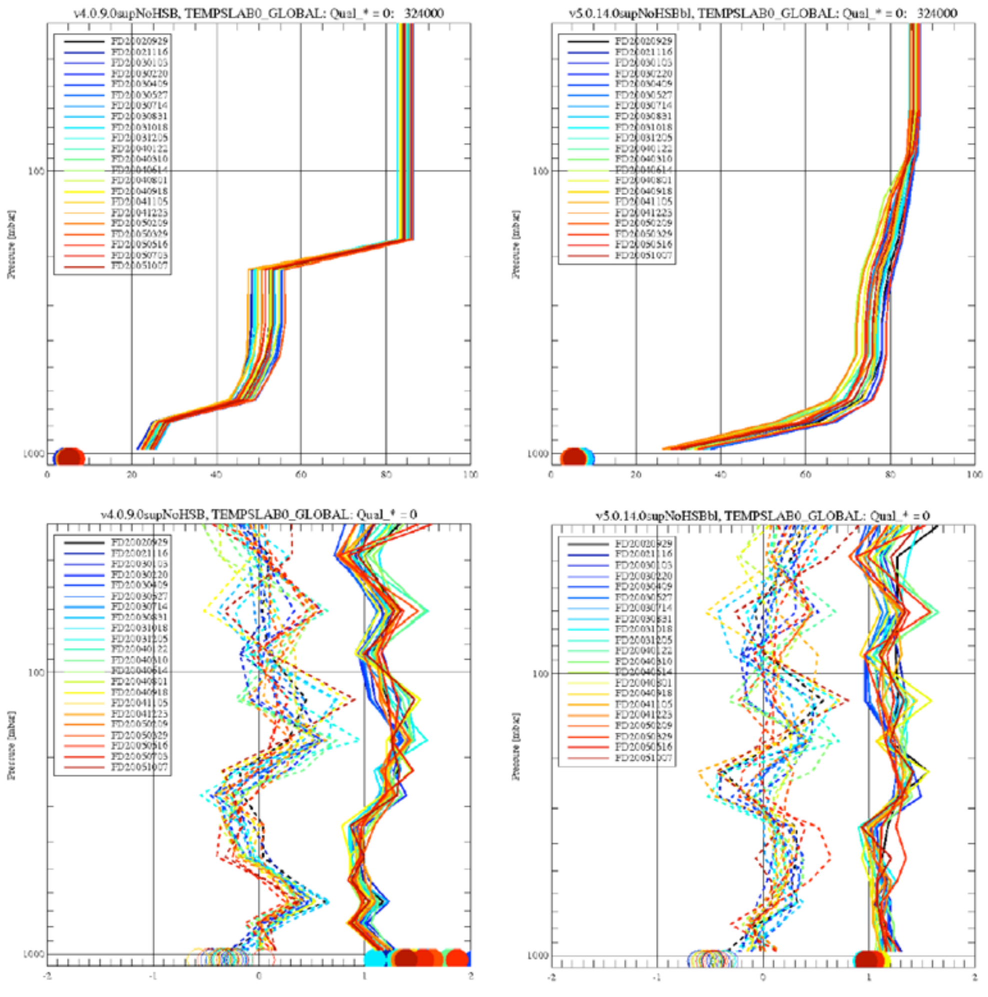

Figure 1: Comparison of V4 (left) and V5 (right) temperature product for a series of focus days (Qual_* = 0).

Top panels are yield as a function of pressure; bottom panels are bias (dashed curves) and RMS (solid curves) with respect to ECMWF profiles. Filled circles at bottom denote surface temperature yield, bias and RMS (**Qual_Surf**=0)

Type of Product

All standard temperature products are level quantities, which means that the values are reported at fixed pressure levels. This differs from layer quantities, which are reported on the fixed pressure levels but represent the layer bounded by the level on which they are reported and the next higher level (in altitude).

For more detail, see **V5_L2_Levels_Layers_Trapezoids.pdf** for a full discussion of level and layer quantities.

Quality Indicators

The quality of the temperature profile is indicated by the parameters **PBest** and **PGood**. Please read **V5_L2_Quality_Control_and_Error_Estimation.pdf** for a complete discussion of the quality indicators, including the V4 legacy quality factors that you used in the previous release.

PBest indicates **TAirStd** is "best" from TOA to the level of **PBest**, i.e. quality = 0 for the **TAIRStd** profile for levels above and including **PBest**.

nBestStd is the index of the lowest altitude level of the **pressStd** and **TAirStd** profiles for which the quality is "best". Levels whose indices are in the range i = **nBestStd**, 28 are therefore marked quality = 0.. It is set to a value of 29 to indicate that none are "best". Take note that **nBestStd** is 1-based (as are arrays in FORTRAN and MATLAB) rather than 0-based (as are arrays in C and IDL).

PGood indicates **TAirStd** is "good" from the level below **PBest** to the level of **PGood**, i.e. quality ≤ 1 for the portion of the **TAirStd** profile above and including the level of **PGood**. If **PBest** is less than **PGood**, then the levels below that of **PBest** and above and including that of **PGood** are flagged as quality = 1 ("good"). If **PBest** = **PGood**, then all levels above and including the common pressure level are flagged quality = 0.

nGoodStd is the index of the lowest altitude level of the **pressStd** and **TAirStd** profiles for which the quality is "good". Levels whose indices are in the range i = **nGoodStd**., **nBestStd**-1 are therefore marked quality = 1. It is set to a value of 29 to indicate that none are "good". Take note that **nGoodStd** is 1-based (as are arrays in FORTRAN and MATLAB) rather than 0-based (as are arrays in C and IDL).

Note that it is possible that **PBest** = **PGood** and **nBestStd** = **nGoodStd**. The **TAirStd** profile below **PGood** is rejected and its quality set = 2 ("do not use").

If the entire temperature profile is rejected, **PBest** = **PGood** = 0 and **nBestStd** = **nGoodStd** = 29. There may, however, still be values in the **TAirStd** profile if some stage of the retrieval was successful. The profile may be simply a excessively noisy full retrieval or the result of the MW-Only stage or of the cloudy regression stage.

The **PBest** and **PGood** indicators allow an altitude discrimination of the point at which the retrieval of the temperature profile begins to encounter difficulties that is finer than the coarser quality indicators of V4 data products (**Qual_Temp_Profile_***).

Caveats

All parameters that are level numbers, such as **nSurfStd, nBestStd and nGoodStd** are 1-based. Those who work in FORTRAN and MATLAB will be unaffected. However, those who work in C and IDL must take care when using nSurfStd and other parameters that are level numbers. The following two expressions yield the same value:

FORTRAN and MATLAB: **pressStd**(**nBestStd**)
C and IDL: **pressStd**[**nBestStd**-1]

The quality indicator is based on the empirical error estimate **TAirStdErr.** The output error estimate may not be consistent with the atmospheric temperature error estimate used by the physical retrieval algorithm. The latter is not written to the output.

Our analysis of V4 retrievals showed that many of the rejected retrievals were of good quality (quality = 1). The error estimate in V5 has improved over that in V4, and so the quality control thresholds in V5 have been relaxed somewhat from that of V4.

In response to the desire of researchers to use retrievals nearby to and within (if possible) tropical storms, a class of retrievals (approximately 10% of the total) are reported in V5 which the entire IR physical retrieval has been rejected. Researchers can against (or for) this class by testing for the signature: **PBest** = **PGood** = 0.0. A secondary filter to apply to this class is to test that **PTropopause** is not equal to -9999. Retrievals passing this second test will have temperature profiles resulting from different retrieval steps, so that they will have different error characteristics and biases, i.e. they do not result from a single retrieval path.

Suggestions for Researchers

We strongly recommend using the **PBest** and **PGood** quality indicators. The values that are set for subsetting data should be carefully chosen, and depend upon how the data are to be used. At the very least, **PGood** should exceed the maximum pressure of interest. If the thrust of the research is comparison with in situ measurements (e.g., radiosondes), then **PBest** should exceed the maximum pressure of interest. The portions of profiles underneath **PSurfStd** are invalid.

Researcher who wish to continue using the V4 quality indicators to filter data should augment **Qual_Temp_Profile_Bot** by applying the additional acceptance condition, 0.0 < **TSurfStdErr** < 5.0.

Researchers who wish to continue using the V4 quality indicators to filter data should augment **Qual_Temp_Profile_Mid** and **Qual_Temp_Profile_Top** by applying the additional acceptance condition, 0.0 < **TAirStdErr** < 10.0 to each level in the 28-element **TAirStdErr** array.

Recommended Papers

Divakarla, M., C. D. Barnet, M. D. Goldberg, L. M. McMillin, E. Maddy, W. Wolf and L. Zhow (2006), Validation of AIRS temperature and water vapor retrievals with matched radiosonde measurements and forecasts, J. Geophys. Res., 111, D09S15, doi:10.1029/2005JD006116

Fetzer E. J., J. Teixeira, E. T. Olsen, E. F. Fishbein (2004), Satellite remote sounding of atmospheric boundary layer temperature inversions over the subtropical eastern Pacific, Geophys. Res. Lett., 31, L17102, doi:10.1029/2004GL020174.

Gao, W., Zhao, F. Gai, C. (2006), Validation of AIRS retrieval temperature and moisture products and their application in numerical models, Acta Metorol. Sinica, Acta Meteorologica Sinica, 64, 271-280.

Susskind J., C. Barnet, J. Blaisdell, L. Iredell, F. Keita, L. Kouvaris, G. Molnar, M. Chahine (2006), Accuracy of geophysical parameters derived from Atmospheric Infrared Sounder/Advanced Microwave Sounding Unit as a function of fractional cloud cover, J. Geophys. Res., 111, D09S17, doi:10.1029/2005JD006272.

Tobin D. C., H. E. Revercomb, R. O. Knuteson, B. M. Lesht, L. L. Strow, S. E. Hannon, W. F. Feltz, L. A. Moy, E. J. Fetzer, T. S. Cress (2006), Atmospheric Radiation Measurement site atmospheric state best estimates for Atmospheric Infrared Sounder temperature and water vapor retrieval validation, J. Geophys. Res., 111, D09S14, doi:10.1029/2005JD006103.

Wu,X. B., Li,J., Zhang,W. J., Wang,F. (2005), Atmospheric profile retrieval with AIRS data and validation at the ARM CART site.

Recommended Supplemental User Documentation

V5_L2_Standard_Pressure_Levels.pdf
V5_L2_Levels_Layers_Trapezoids.pdf
V5_L2_Quality_Control_and_Error_Estimation.pdf
V5_CalVal_Status_Summary.pdf
V5_Retrieval_Channel_Sets.pdf
V5_Retrieval_Flow.pdf

AIRS Standard Moisture Product

The AIRS standard moisture product is the result of the combined IR/MW retrieval. See the MW-Only product (above) for moisture products derived solely from the microwave data.

Field Name	Dimension per FOV	Description
PSurfStd	1	Surface pressure, interpolated from the NCEP GFS forecasts and local DEM topography, (mb)
pressH2O	H2OPressureLev=15	Pressure levels delimiting moisture layers and upon which moisture products are reported, (mb)
H2OMMRStd	H2OPressureLay=14	Retrieved Water Vapor Mass Mixing Ratio Profile, (gm/kg)
H2OMMRStdErr	H2OPressureLay=14	Error estimate for H2OMMRStd, (gm/kg)
Water_Resid_Ratio	1	Internal retrieval quality indicator; residuals of moisture channels compared to predicted uncertainty, (unitless)
H2OMMRSat	H2OPressureLay=14	Saturation Water Vapor Mass Mixing Ratio Profile over equilibrium phase, (gm/kg)
H2OMMRSat_liquid	H2OPressureLay=14	Saturation Water Vapor Mass Mixing Ratio Profile over liquid phase, (gm/kg)
totH2OStd	1	Retrieved Total Precipitable Water Vapor, (kg/m^2)
totH2OStdErr	1	Error Estimate for TotPrecipWatVap, (kg/m^2)
H2O_verticality	H2OFunc=11	Sum of the rows of H2O_ave_kern, (unitless)
num_H2O_Func	1	Number of valid entries in each dimension of H2O_ave_kern

Description

The atmospheric precipitable water vapor profile (**H2OMMRStd**) is the retrieved mean mass mixing ratio between two **pressH2O** levels (see **V5_L2_Standard_Pressure_Levels.pdf**). It is reported on the lower altitude bounding pressure level bounding the layer. Standard pressure levels are arranged in order of decreasing pressure. The pressure levels on which moisture products are reported, **pressH2O**, are the same as the first 15 levels of the 28 available (i.e. for **PressStd** ≥ 50mb). The value quoted is the mean mass mixing ratio between that level and the next higher level. The value quoted on the lowest altitude pressure level above the surface (index = **nSurfStd**, which may be 1, 2, …, 15) is the mean mass mixing ratio in the layer bounded by the next higher level and the surface.

H2OMMRSat_liquid and **H2OMMRSat** both provide profiles of the integrated mass of water vapor in saturated equilibrium between **pressH2O** levels divided by the integrated mass of dry air. **H2OMMRSat_liquid** assumes equilibrium with liquid water. **H2OMMRSat** is in equilibrium with liquid so long as the **TAirSup** (100 level profile) exceeds 273.15 K. If **TAirSup** drops below that threshold, the saturation calculation shifts to that over ice water. Thus within a layer in which the temperature crosses 273.15 K, the calculation will shift between saturation over liquid to that over ice to derive its integrated mass of water vapor. Near the surface the two saturation profiles are identical, but they will diverge in the case that the temperature profile crosses the threshold. The constituent relationship employed is that of Murphy and Koop (2005).

totH2OStd is the total column moisture burden from top of atmosphere (TOA) to the surface. It is impossible for a user to integrate **H2OMMRStd** to compare the result to **totH2OStd**. The standard product moisture profile does not have sufficient vertical resolution, and the intrusion of topography into the final layer over land further complicates the calculation.

Important note: The V4 saturation mixing ratio was calculated at the temperature of the standard pressure levels using Buck (1981). The calculation took into account the shift from liquid to ice at 273.15 K, but the saturation profile was not an integration over each layer. Instead, it was a level quantity at the standard pressure levels. It could not be directly compared to the observed moisture profile, which was a layer quantity. Doing so would result in absurd estimates of relative humidity, the most benign effect being a dry bias.

H2O_verticality is an 11 point vector computed by summing the columns of the 11x11 H_2O averaging kernel, **H2O_avg_kern**, stored in the AIRS Level 2 Support Product. The peak of **H2O_verticality** indicates the vertical location of the maximum sensitivity of the H_2O product and the magnitudes of **H2O_verticality** are a rough measure of the fraction of the retrieval determined from the data as opposed to the first guess. Values near unity should be considered highly determined from the measurement, while smaller values indicate the retrieval contains a large fraction of the first guess.

NOTE: the problem with associating the verticality with a total column averaging kernel is that it neglects the fact that the retrieval can only move as superpositions of the trapezoids. Convolution using the verticality alone will not account for the possibility that the “independent H_2O profile” contains structure that the trapezoids can or cannot resolve.

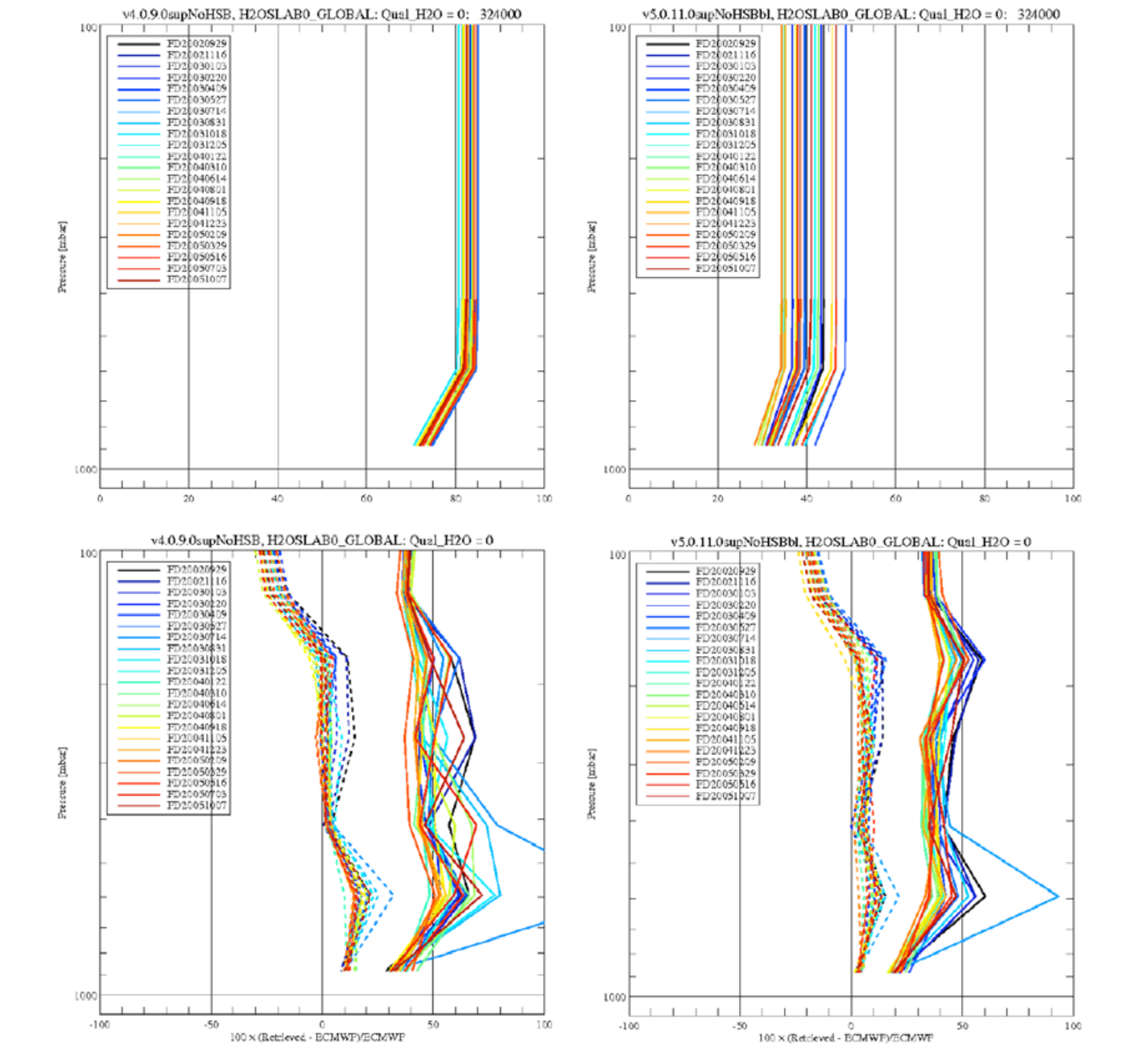

Figure 2: Comparison of V4 (left) and V5 (right) moisture product (Qual_H2O=0) for a series of focus days.

Top panels are yield as a function of pressure; bottom panels are bias (dashed curves) and RMS (solid curves) with respect to ECMWF profiles.

Type of Product

All standard moisture product profiles are layer quantities, which means that the values are reported on the fixed pressure levels but represent the layer bounded by the level on which they are reported and the next higher level (in altitude).

For more detail, see **V5_L2_Levels_Layers_Trapezoids.pdf** for a full discussion of level and layer quantities.

Quality Indicators

Qual_H2O – pertains to **totH2OStd**.

For the **H2OMMRStd** profile, interpret **Qual_H2O** as follows:

0 = best, entire profile judged suitable for assimilation and statistical climate studies
(final IR retrieval and **totH2OstdErr**/**totH2Ostd** < 0.35 and **PBest** = **PsurfStd**)

1 = profile for pressures less than **PBest** judged suitable for assimilation; profile for pressures equal to or greater than **PBest** judged suitable for statistical climate studies; entire profile good for inclusion in Level 3 gridding
(final IR retrieval and **totH2OstdErr**/**totH2Ostd** < 0.35 and 300mb < **PBest** < **PsurfStd**)

2 = entire profile rejected, researchers should not use moisture profile

Caveats

Qual_H2O is based on **H2OMMRStdErr**. However there are indications that the water vapor profile error estimate may depend as well on **PBest** and **PGood.**

We have yet to determine the altitude at which AIRS loses sensitivity to water vapor. However comparison with MLS indicates that AIRS is reliable for pressures greater than 200 mb. The upper bound to the altitude at which AIRS loses sensitivity depends upon the amount of water vapor present.

Suggestions for Researchers

In the case that **Qual_H2O** = 1, researchers must use the value of **PBest** to identify the portion of the moisture profile which is suitable for assimilation and which is of somewhat lesser quality but is suitable for statistical climate studies. The portion of the moisture profile for which **pressH2O** ≤ **PBest** is suitable for assimilation, whereas the portion for which **pressH2O** > **PBest** is of lesser quality.

We recommend that researchers also employ the estimated error, **H2OMMRStdErr**, as an additional filter to excise those profiles in which the estimated error is negative or greater than 50% of **H2OMMRStd**.

Recommended Papers

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Livingston, J., E.J. Fetzer et al. (2007), Comparison of water vapor measurements by airborne Sun photometer and near-coincident in situ and satellite sensors during INTEX/ITCT 2004, J. Geophys. Res., 112, D12S16, doi:10.1029/2006JD007733.

Miloshevich L. M., H. Vömel, D. N. Whiteman, B. M. Lesht, F. J. Schmidlin, F. Russo (2006), Absolute accuracy of water vapor measurements from six operational radiosonde types launched during AWEX-G and implications for AIRS validation, J. Geophys. Res., 111, D09S10, doi:10.1029/2005JD006083.

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Tobin D. C., H. E. Revercomb, R. O. Knuteson, B. M. Lesht, L. L. Strow, S. E. Hannon, W. F. Feltz, L. A. Moy, E. J. Fetzer, T. S. Cress (2006), Atmospheric Radiation Measurement site atmospheric state best estimates for Atmospheric Infrared Sounder temperature and water vapor retrieval validation, J. Geophys. Res., 111, D09S14, doi:10.1029/2005JD006103.

Recommended Supplemental User Documentation

V5_L2_Standard_Pressure_Levels.pdf
V5_L2_Levels_Layers_Trapezoids.pdf
V5_L2_Quality_Control_and_Error_Estimation.pdf
V5_CalVal_Status_Summary.pdf
V5_Retrieval_Channel_Sets.pdf
V5_Retrieval_Flow.pdf

AIRS Standard Surface Product

Field Name	Dimension per FOV	Description
PSurfStd	1	Surface pressure, interpolated from the NCEP GFS forecasts and local DEM topography, (mb)
nSurfStd	1	Index of lowest altitude pressStd element which is above the surface (1-based) (unitless)
GP_Surface	1	Geopotential height of surface (above mean sea level), (m)
TSurfStd	1	Surface skin temperature, (K)
TSurfStdErr	1	Error estimate for TSurfStd, (K)
TSurfAir	1	Retrieved Surface Air Temperature (K)
TSurfAirErr	1	Error Estimate for TSurfAir (K)
numHingeSurf	1	Number of IR hinge points for surface emissivity and reflectivity, (unitless)
freqEmis	HingeSurf(=100)	Frequencies for surface emissivity and reflectivity in order of increasing frequency. Only the first numHingeSurf elements are valid. (cm^{-1})
emisIRStd	HingeSurf(=100)	Spectral IR surface emissivities in order of increasing frequency from 649 to 2666 cm^{-1} by a series of “hinge points” that differ between land and ocean. Only the first numHingeSurf elements are valid. (unitless)
emisIRStdErr	HingeSurf(=100)	Error estimate, (unitless)
Surf_Resid_Ratio	1	Internal retrieval quality indicator; residuals of surface channels compared to predicted uncertainty (unitless)

PSurfStd is not an AIRS product. It is interpolated from the AVN forecasts and corrected using the local DEM topography of the retrieval FOV and is used as an input to the AIRS processing.

Description

The AIRS standard surface product is the result of the combined IR/MW retrieval. See the MW-Only product (above) for surface products derived solely from the microwave data.

The initial surface emissivity over ocean (**landFrac** > 0.99, non-frozen, **MWSurfClass** = 2) follows the shape of the Masuda model as updated by Wu and Smith (1997) as recomputed at higher spectral resolution by van Delst and Wu (http://airs2.ssec.wisc.edu/~paulv/#IRsse). Their adjustable parameter set for a wind speed of 5 meters/sec.

The initial surface emissivity over all other surface classes (e.g., land and ice), has been set by a regression. Thus the behavior of MWSurfClass = 2 cases will differ from all other cases because of the different initialization of **emisIRStd** before carrying out the first cloud clearing. The subsequent regression retrieval determines a spectral shape that is then used as an updated state for the final retrieval. This regression with shortwave variability has been greatly improved in V5. The final retrieval then adjusts the spectral shape, over land or ocean, with four degrees of freedom. Although algorithm improvements include better treatment of land surface heterogeneity and training over land, the AIRS surface emissivity product over land and ice is still being refined.

There has been considerable confusion over the years about the use of "hinge points" to define the emissivity and reflectvity spectrum. Different retrievals may use different sets of hinge points. There is no physical meaning to the choice of hinge points. They are purely a method of describing a piecewise linear (in frequency) curve in spectral space. To compute a surface emissivity at a particular frequency, the researcher should interpolate in frequency between the emissivities provided at adjacent hinge points. Nothing philosophical should be read into the choice of hinge points or why they vary among profiles.

For modeling the upwelling radiance surfaces are assumed Lambertian, except for the short wave component of the reflected solar component. In this case, the reflectivity is that required to account for the reflected incoming solar component that may not be Lambertian.

The surface air temperature (**TSurfAir**) is obtained from the 100-level support product air temperature profile (**TAirSup**) using interpolation that is linear in the logarithm of the support pressure (**pressSup**).

Note that **TSurfAir** will equal **TAirStd**(**nSurfStd**) only if **pressStd**(**nSurfStd**) is equal to **PSurfStd**. This will seldom be the case.

Type of Product

The AIRS surface products are all level quantities, describing the state at **PSurfStd**.

University of Wisc	AIRS V4	AIRS V5

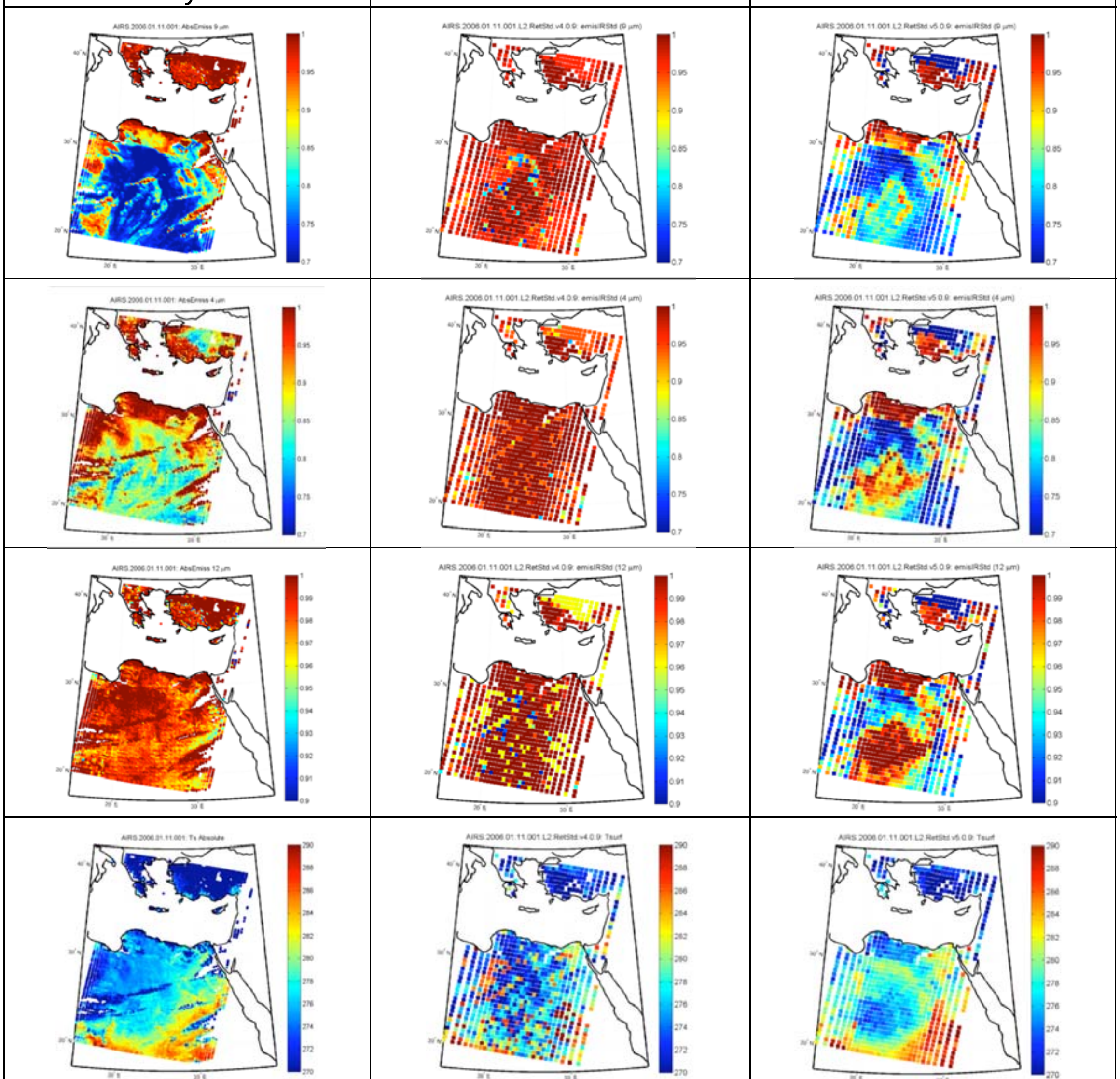

Figure 3: Comparison of UW Land Surface Emissivity with AIRS emisIRStd (Robert Knuteson of UWISC-Madison)

Row 1: 9mm emissivity   Row 2: 4mm emissivity

Row 3: 12mm emissivity   Row 4: surface skin temperature

Quality Indicators

Qual_Surf – pertains to **TSurfStd, emisIRStd and rhoIRStd**

It is set as follows:

Over Ocean:

0 = best, if **TSurfStdErr** < 0.8 K

1 = good
if Lat > -40° and **TSurfStdErr** < 1.0 K
if Lat < -60° and **TSurfStdErr** < 1.75 K
if -60° ≤ Lat ≤ -40°
and **TSurfStdErr** < 1.75–0.0375•(60+Lat)

2 = do not use, if TSurfStdErr fails test

Over Land:

1 = good, if **PBest** ≥ 300 mb

2 = do not use, if **PBest** < 300 mb

The philosophy for quality control over ocean vs all other cases differs. Over ocean the quality control attempts to identify quite good cases because we think that is what researchers require. If the yield is not appropriate for a particular application, users are encouraged to use **TSurfStdErr** as a more precise filter. Over land, other data sources are not as readily available and we have chosen to mark no cases as "best" pending further refinement and validation of the emissivity products, but mark a large selection of cases as "good" to ensure adequate coverage for production of 8-day and monthly means for climate studies.

Caveats

The AIRS surface emissivity/reflectivity products are still being refined.

emisIRstd has peaks in [1.03 - 1.05] for different days, surfaces, day/night, and hinge points. The worst cases (up to 33% of all profiles) are night cases with frozen surfaces.

emisIRstd represents the emissivity from 649 cm^{-1} to 2666 cm^{-1} by a series of "hinge points" which will differ between land and ocean because of the internal processing paths and assumptions. The user must read **freqEmis** to know the values of the **numHingeSurf** hinge points for each profile, and then interpolate linearly in wavelength to find the emissivity at a particular frequency.

TSurfAir sometimes differs by more than 2.5 K from the interval defined by the values of **TAirStd** for the levels immediately above and below the surface.

Suggestions for Researchers

None at this time.

Recommended Papers

Chen, Francis, Miller (2002), Surface temperature of the Arctic: Comparison of TOVS satellite retrievals with surface observations, J. Climate, 15, 3698–3708. DOI: 10.1175/1520-0442(2002)015<3698:STOTAC>2.0.CO;2

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Knuteson et al (2003), Aircraft measurements for validation of AIRS land surface temperature and emissivity products at the Southern Great Plains validation site, Fourier Transform Spectroscopy (Trends in Optics and Photonics Series Vol.84). 138.

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Wu and Smith (1997), Emissivity of rough sea surface for 8-13 μm: modeling and verification," Appl. Opt. 36, 2609-2619

Recommended Supplemental User Documentation

V5_L2_Standard_Pressure_Levels.pdf

V5_L2_Quality_Control_and_Error_Estimation.pdf

V5_CalVal_Status_Summary.pdf

V5_Retrieval_Channel_Sets.pdf

V5_Retrieval_Flow.pdf

AIRS Standard Ozone Product

Field Name	Dimension per FOV	Description
PSurfStd	1	Surface pressure, interpolated from the NCEP GFS forecasts and local DEM topography, (mb)
pressStd	StdPressureLev=28	Pressure levels upon which ozone profiles are reported, (mb)
nSurfStd	1	Index of lowest altitude pressStd element which is above the surface (1-based), (unitless)
O3VMRStd	StdPressureLay=28	Retrieved Ozone Volume Mixing Ratio Profile (vmr), (unitless)
O3VMRStdErr	StdPressureLay=28	Error estimate (vmr), (unitless)
totO3Std	1	Retrieved Total Ozone Burden, (DU)
totO3StdErr	1	Error estimate, (DU)
num_O3_Func	1	Number of valid entries in each dimension of O3_ave_kern
O3_verticality	O3Func=9	Sum of rows of O3_ave_kern, (unitless)
O3_Resid_Ratio	1	Internal retrieval quality indicator; residuals of O3 channels as compared to predicted uncertainty, (unitless)
O3_dof	1	Degrees of freedom, measure of amount of information in O3 retrieval, (unitless)

Description

The AIRS standard ozone product is a product of the IR stage of the combined IR/MW retrieval. The ozone profile (**O3VMRStd**) is the retrieved volume mixing ratio (ratio of number of O_3 molecules to the number of molecules of air in a unit volume) between two **pressStd** levels. It is reported on the lower altitude bounding pressure level bounding the layer. Standard pressure levels are arranged in order of decreasing pressure. The ozone products are reported on all 28 available. The value quoted is the mean volume mixing ratio between that level and the next higher level. The value quoted on the lowest altitude pressure level above the surface (index = **nSurfStd**, which may be 1, 2, …, 15) is the mean volume mixing ratio in the layer bounded by the next higher level and the surface.

totO3Std is the integrated column amount of O_3 from the top of the atmosphere (TOA = 0.005 mb) to the surface. This quantity is computed by summing the 100 column density values, **O3CDsup,** contained in the AIRS Level 2 Support Products file with the appropriate weighting applied to the bottom layer which contains the surface. Layers below the surface are not included in this sum.

O3_dof provides a measure of the amount of information in the O_3 retrieval. It is computed by summing the diagonal elements of the 9x9 O_3 averaging kernel, **O3_avg_kern**, stored in the AIRS Support Product files.

O3_verticality is a 9 point vector computed by summing the columns of the 9x9 O_3 averaging kernel, **O3_avg_kern**, stored in the AIRS Level 2 Support Product. The peak of **O3_verticality** indicates the vertical location of the maximum sensitivity of the O_3 product and the magnitudes of **O3_verticality** are a rough measure of the fraction of the retrieval determined from the data as opposed to the first guess. Values near unity should be considered highly determined from the measurement, while smaller values indicate the retrieval contains a large fraction of the first guess.

NOTE: the problem with associating the verticality with a total column averaging kernel is that it neglects the fact that the retrieval can only move as superpositions of the trapezoids. Convolution using the verticality alone will not account for the possibility that the “independent O_3 profile” contains structure that the trapezoids can or cannot resolve.

O3_VMR_eff is contained in the AIRS Level 2 Support Products file and is the retrieved volume mixing ratio (ratio of number of O_3 molecules to the number of molecules of air in a unit volume) for a layer defined by the faces of a CO trapezoidal retrieval function. The boundaries of faces of these layers are specified in **O3_trapezoid_layers** in which is an array of 1-based **pressSup** level indices (see **V5_L2_Support_Pressure_Levels.pdf**). In V5, there are 9 such layers corresponding to the 9 trapezoidal retrieval functions utilized for O_3.

Ozone retrieval methodology for V5 has significantly changed from V4 and as described in Susskind et al. [2003], namely in the derivation of the first-guess, channel selection, and “noise propagation threshold” used in the physical (final) retrieval.

In previous versions, the first guess for the ozone profile was regression-based using European Centre for Medium-Range Weather Forecast (ECMWF) ozone profiles as the training set (see Goldberg et al. [2003]). Instead of using regression, AIRS V5 uses an observationally-based climatology developed for Version 8 TOMS and SBUV [McPeters et al., 2003], which is month-by-month on 10° latitude bins.

To make a look-up table suited to the AIRS retrieval software, ozone mixing ratios were interpolated by latitude and altitude and converted to slab columns on the AIRS 100-level support grid using the "Partial Column" approximation formula in Ziemke et al. [2001]. Where climatological data did not extend the highest or lowest pressure levels of the AIRS support grid, mixing ratio "endpoints" were assumed to extend to such regions.

The channel selection has been extended from 26 (in V4) to 41, and includes the peak of the P-branch in the ozone 10 μm band. Finally, the "noise propagation threshold," DB_{max}, discussed in Susskind et al. [2003], has been effectively doubled, resulting in less damping of the final profile.

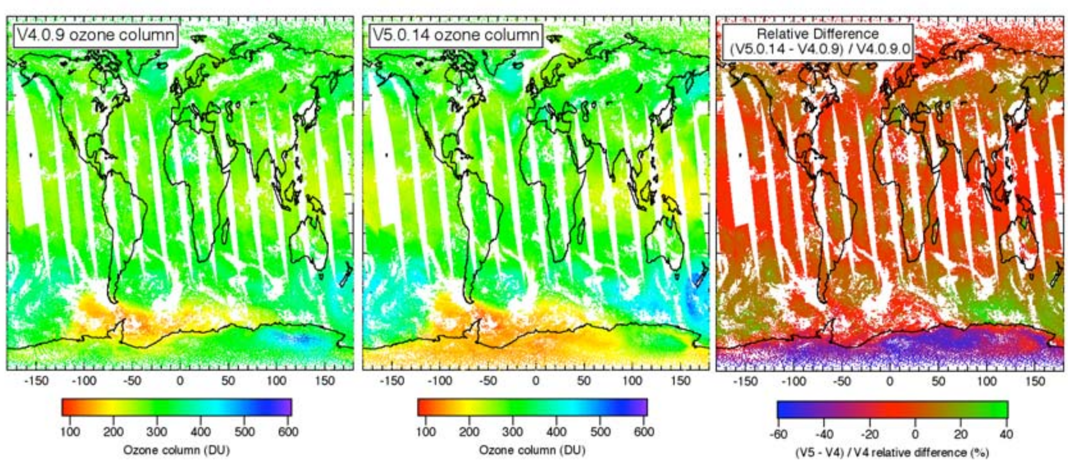

Figure 4: Total column ozone retrievals from V4.0.9.0 (left panel) and V5.0.14.0 (middle panel), and relative difference (right panel) for October 7, 2005 daytime.

Only retrievals with a Qual_O3=0 flag are shown. V5 ozone is slightly less in the tropical western Pacific and northern Indian Ocean region, slightly higher in the region south of New Zealand and significantly lower on the Antarctic continent.

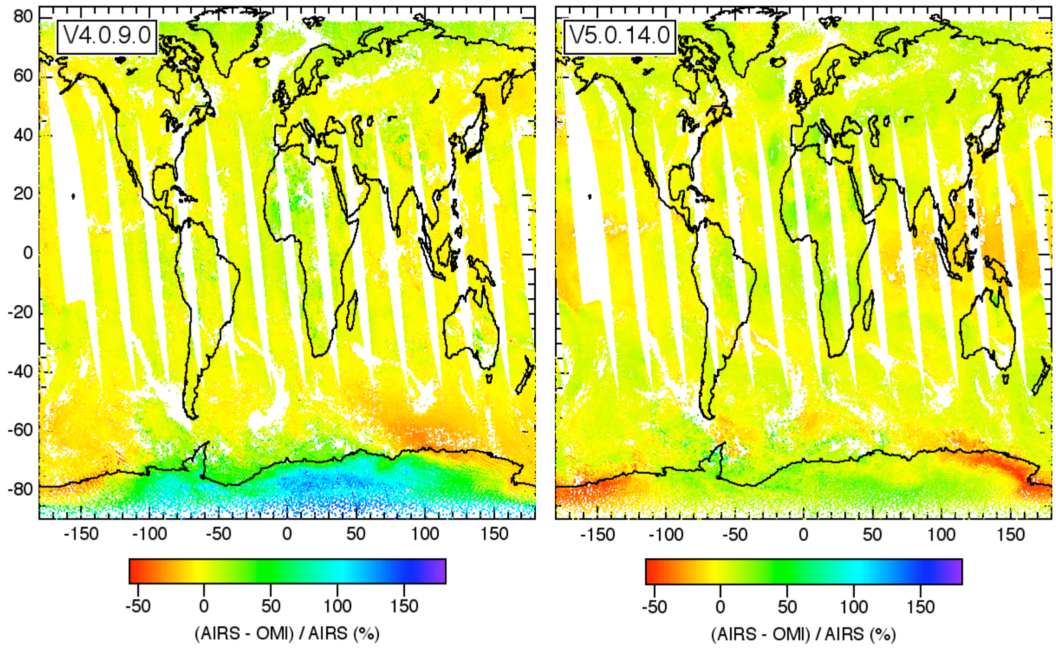

Figure 5: Relative difference between AIRS and OMI total column ozone on October 7, 2005 using V4.0.9.0 (left panel) and V5.0.14.0 (right panel).
AIRS was compared to OMI where the geographical center of an AIRS retrieval was within a 0.25°x0.25° gridbox of the OMI high-resolution L3 product.

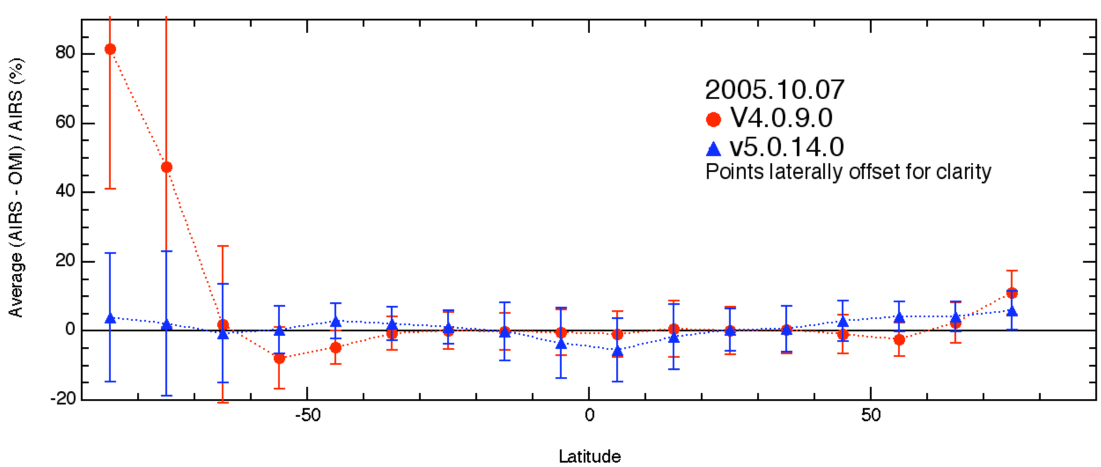

Figure 6: Average relative difference between AIRS and OMI for daytime October 7, 2005, binned by latitude.
Error bars are 1σ standard deviation.

The effect on retrievals of switching from a regression-based to a climatological first guess at several sites is illustrated in the figure below, where the left panels show AIRS-sonde biases using regression as a first guess, while the right panels show such biases using climatology as a first guess. (AIRS V5.0.7 was used for this illustration, however spot testing indicate negligible column differences between V5.0.7 and V5.0.14.) Using a climatology reduces biases in the mid- to lower-troposphere where AIRS has little sensitivity. Stratospheric biases are about the same. Upper tropospheric biases have been reduced in tropical regions, but are somewhat worse in mid-latitude regions.

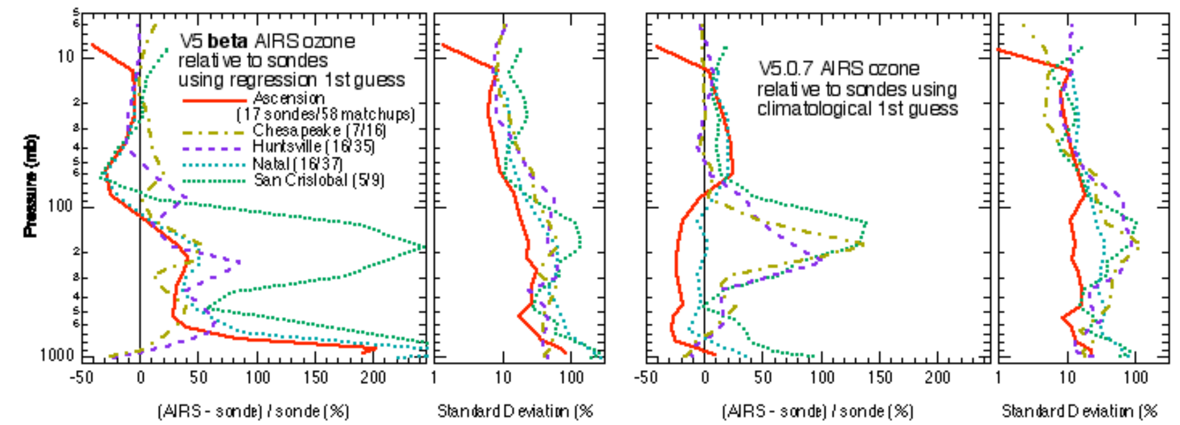

Figure 7: Average relative differences and standard deviations of AIRS retrievals to ozonesondes with regression first guess (left panels) and V5 climatological first guess (right panels).

AIRS-sonde matchups occurred with AIRS observation within 3 hours and 50 km of sonde launch. Sonde profiles were smoothed to AIRS standard vertical layer depths prior to comparison.

Validation of V5 AIRS ozone against coincident ozonesondes, aircraft measurements and ground-based Dobson spectrometers is ongoing.

Type of Product

O3VMRStd is a layer quantity, which means that the values are reported on the fixed pressure levels but represent the layer bounded by the level on which they are reported and the next higher level (in altitude).

For more detail, see **V5_L2_Levels_Layers_Trapezoids.pdf** for a full discussion of level and layer quantities.

Quality Indicators

Qual_O3 – pertains to the full **O3VMRStd** profile and burden, **totO3Std**

0 = best,
ozone product judged suitable for assimilation and statistical climate studies
(final IR retrieval and **totH2OstdErr**/**totH2Ostd** < 0.35)

2 = rejected, researchers should not use ozone product.

Caveats

Qual_O3 is set to 0 if **totH2OstdErr/totH2OStd** ≤ 0.35 and the final IR retrieval is the atmospheric state of the reported products.

Errors in temperature profiles and water vapor mixing ratios will adversely affect the ozone retrieval. Significant biases (0 - 100%) may exist in the region between ~300 mb and ~80 mb, such biases currently being evaluated. Ozone mixing ratio data may not be reliable at pressures greater than 300 mb or if the tropospheric mixing ratio is less 100 ppbv, however results may be qualitatively correct under conditions of high upper tropospheric ozone (such as in a tropopause fold). Mixing ratios and columns should not be considered reliable under conditions of very low skin temperatures (< 240 K).

The error fields, **O3VMRStdErr** and **totO3StdErr**, are fixed as a fraction of the ozone amount and should not be used.

The ozone first guess used to initialize the V5 retrieval is likely too high at pressures below ~0.5 mb (altitudes above ~55 km) due to an error in extrapolation in its creation. This has a negligible effect on **totO3Std** and the portion of **O3VMRStd** profile at pressures greater than 0.5 mb. At pressures lower than 0.5 mb, biases in **O3VMRStd** are estimated to be between ~10% to ~50%. The extrapolation error occurs in the lowest 6 pressure levels of the support pressure level array (i.e., in the L2 Support Product **O3CDSup** array elements 1, 2, 3, 4, 5 and 6.

Suggestions for Researchers

None at this time.

Recommended Papers

Bian J., A. Gettelman, H. Chen, L. L. Pan (2007), Validation of satellite ozone profile retrievals using Beijing ozonesonde data, J. Geophys. Res., 112, D06305, doi:10.1029/2006JD007502.

Chen, Francis, Miller (2002), Surface temperature of the Arctic: Comparison of TOVS satellite retrievals with surface observations, J. Climate, 15, 3698–3708. DOI: 10.1175/1520-0442(2002)015<3698:STOTAC>2.0.CO;2

Goldberg, M. D., Y. Qu, L. M. McMillin, W. Wolf, L. Zhou and M. Divakarla (2003), AIRS near-real-time products and algorithms in support of operational numerical weather prediction, IEEE. Trans. Geosci. Remote Sens., 41 (2), 379-389.

Levelt, P. F., et al. (2006), Science objectives of the Ozone Monitoring Instrument, IEEE Trans. Geosci. Remote Sens., 44, 1199-1208.

McPeters, R. D., J. A. Logan, G. J. Labow (2003), Ozone Climatological Profiles for Version 8 TOMS and SBUV Retrievals, Eos Trans. AGU, 87 (52), Fall Meet. Suppl., Abstract A21D-0998.

Morris G. A., et al. (2006), Alaskan and Canadian forest fires exacerbate ozone pollution over Houston, Texas, on 19 and 20 July 2004, J. Geophys. Res., 111, D24S03, doi:10.1029/2006JD007090.

Susskind, J., C. D. Barnet, and J. M. Blaisdell (2003), Retrieval of atmospheric and surface parameters from AIRS/AMSU/HSB data in the presence of clouds, IEEE Trans. Geosci. Remote Sens., 41 (2), 390 – 409.

Tian B., Y. L. Yung, D. E. Waliser, T. Tyranowski, L. Kuai, E. J. Fetzer, F. W. Irion (2007), Intraseasonal variations of the tropical total ozone and their connection to the Madden-Julian Oscillation, Geophys. Res. Lett., 34, L08704, doi:10.1029/2007GL029451.

Ziemke, J. R., S. Chandra, and P. K. Bhartia (2001), “Cloud slicing”: A new technique to derive upper tropospheric ozone from satellite measurements, J. Geophys. Res., 106 (D9), 9853-9867.

Recommended Supplemental User Documentation

V5_L2_Standard_Pressure_Levels.pdf

V5_L2_Quality_Control_and_Error_Estimation.pdf

V5_CalVal_Status_Summary.pdf

V5_Retrieval_Channel_Sets.pdf

V5_Retrieval_Flow.pdf

AIRS Standard Cloud Product and Outgoing Longwave Radiation (OLR)

Field Name	Dimension per FOV	Description
numCloud	1	Number of retrieved cloud layers (can be 0,1 or 2), (unitless)
CldFrcStd	3x3x2	Effective cloud fraction in each of 9 AIRS spots associated with the AMSU FOV, in order of increasing pressure. Only first numCloud (3x3) values are valid, (unitless)
CldFrcStdErr	3x3x2	Error estimate for CldFrcStd, (unitless)
PCldTopStd	2	Cloud top pressures for each valid cloud layer, (mb)
PCldTopStdErr	2	Error estimate for PCldTopStd, (mb)
TCldTopStd	2	Cloud top temperatures for each valid cloud layer, (K)
TCldTopStdErr	2	Error estimate for TCldTopStd, (K)
all_spots_avg	1	Indicator that cloud clearing was or was not applied, (unitless)
Cloud_Resid_Ratio	1	Internal retrieval quality indicator, ratio of residual of cloud channels to predicted uncertainty, (unitless)
Initial_CC_score	1	Indicator how well cloud cleared radiances match radiances reconstructed from eigenvectors, (unitless)

Field Name	Dimension per FOV	Description
olr	1	Outgoing longwave radiation flux integrated over 2 to 2800 cm^{-1}, (W/m^2)
olr_err	1	Error estimate for olr, (W/m^2)
clrolr	1	Clear sky outgoing longwave radiation flux integrated over 2 to 2800 cm^{-1}, (W/m^2)
clrolr_err	1	Error estimate for clrolr, (W/m^2)
num_clear_spectral_indicator	1	Number of 9 IR spots in AMSU FOV which are clear according to spectral_clear_indicator. Set to -1 when the spectral clear indicator could not be applied to any of the spots. Note that the spectral clear indicator is not validated for land scenes, (unitless)
spectral_clear_indicator	3x3	Flag telling whether IR spot scene in AMSU FOV was flagged as clear by a spectral filter. Set to 2 if judged ocean and clear and 1 if judged ocean and not clear. Only ocean filter is validated, (unitless)

Description

The combined IR/MW algorithm retrieves 0, 1 or 2 cloud heights within an AMSU FOV (geospatial extent is ~45 km at nadir). If there are two reported formations, the first is the one at the higher altitude.

PCldTopStd is the retrieved cloud top pressure for each reported cloud height, and **PCldTopStdErr** is the associated error at the same horizontal resolution. In addition, the cloud top temperature and its associated error, **TCldTopStd** and **TCldTopStdErr,** are also reported for the same cloud formations. These are interpolated from the AIRS **TAirStd** and **TAirStdErr** fields.

The radiance contrast among the 9 AIRS spots (each of geospatial extent ~15 km at nadir) within the AMSU FOV is used to derive two other 3x3 fields for each cloud formation, **CldFrcStd** and **CldFrcStdErr**. The values in both range between 0.0 and 1.0. **CldFrcStd** is a combination of cloud emissivity and field-of-view cloud coverage. In the event that two cloud heights are reported, the sum over both formations of **CldFrcStd** does not exceed 1.0. If **Qual_Cloud_OLR** = 1, then the **CldFrcStd** array is set to the average cloud fraction within the AMSU FOV (i.e., all values are identical). This occurs in ~10% of the retrievals and there are usually two cloud formations in this case.

Outgoing longwave radiation (**olr**) is not directly measured, but is calculated from the retrieved state using a separate rapid algorithm documented in Mehta and Susskind (1999) and NASA Technical Report GSFC/CR-1999-208643. The surface emissivity in spectral regions not measured by AIRS is assumed to be the same as at the nearest spectral point for which an emissivity is obtained. The effective cloud fraction (cloud fraction multiplied by cloud emissivity) is assumed constant throughout the spectrum and is retrieved based on the 11 micron region. Future versions may relax these assumptions.

Clear-sky outgoing longwave radiation (**clrolr**) is not directly measured, but is calculated from the retrieved state using a separate rapid algorithm documented in Mehta and Susskind (1999) and NASA Technical Report GSFC/CR-1999-208643. The surface emissivity in spectral regions not measured by AIRS is assumed to be the same as at the nearest spectral point for which an emissivity is obtained. Future versions may relax this assumption.

Type of Product

The cloud formation products are level quantities, thus that the values are reported at discrete pressure levels. The OLR products are integrated values for the radiances that would be observed at the TOA.

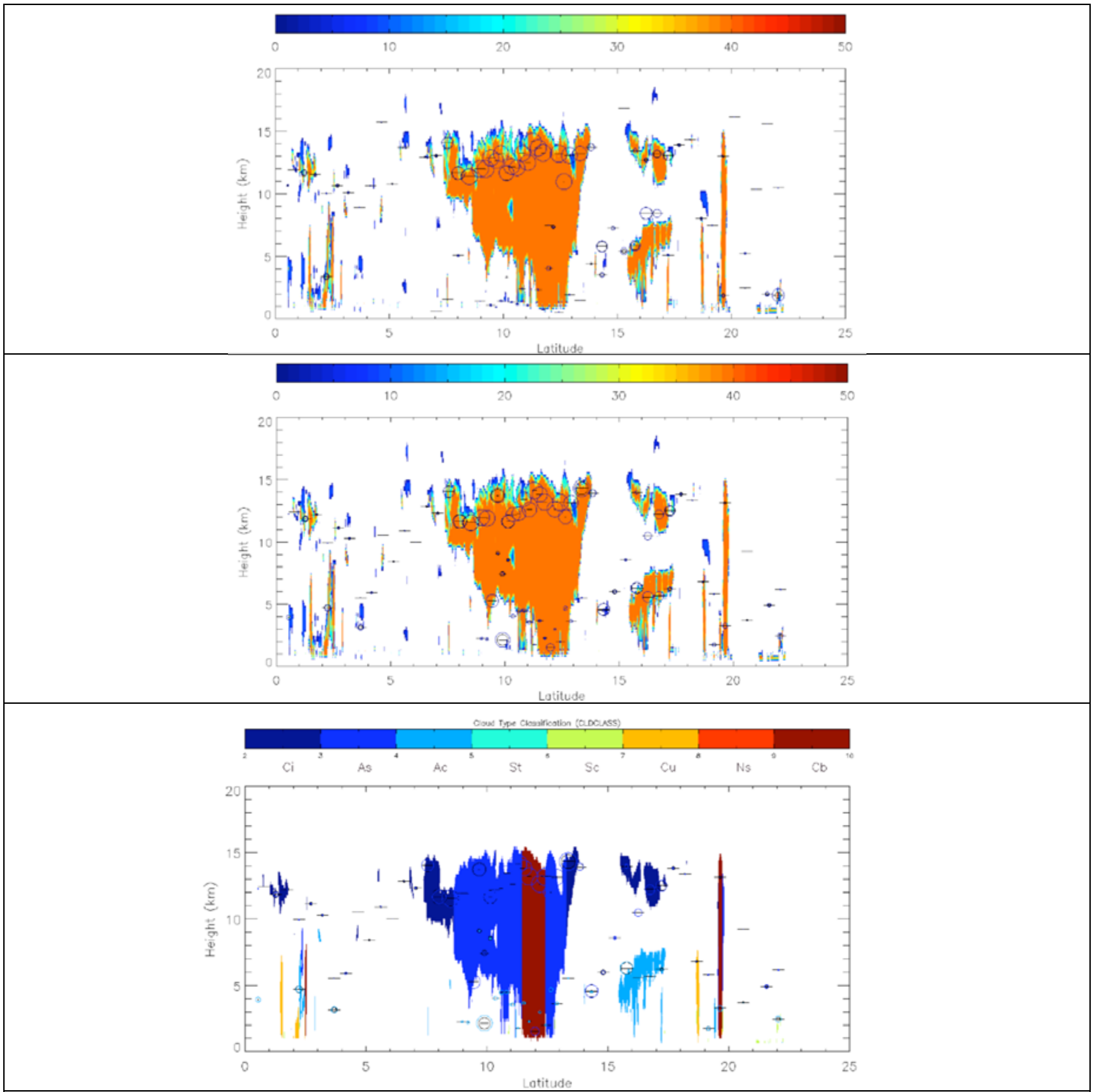

Figure 8: Comparison of AIRS V4 and V5 cloud product and Cloudsat cloud mask with confidence values colorized for a granule in the tropical Western Pacific.

Cloudsat mask values of 10 or less are highly questionable because of reduced sensitivity and contributions from noise. The authors of the Cloudsat cloud confidence mask are Jay Mace and Roger Marchand (Mace et al. 2007), while the cloud classification mask is authored by Zhien Wang and Ken Sassen. The AIRS Effective Cloud Fraction (**CldFrcStd**) is linearly proportional to the diameter of circles, with larger diameters equal to larger **CldFrcStd**. AIRS 2-layer height retrieval (**PCldTopStd**) is superimposed as horizontal lines. Top panel compares AIRS V4 to Cloudsat; Middle panel compares AIRS V5 Bottom panel overlays AIRS V5 product on Cloudsat cloud classification product.

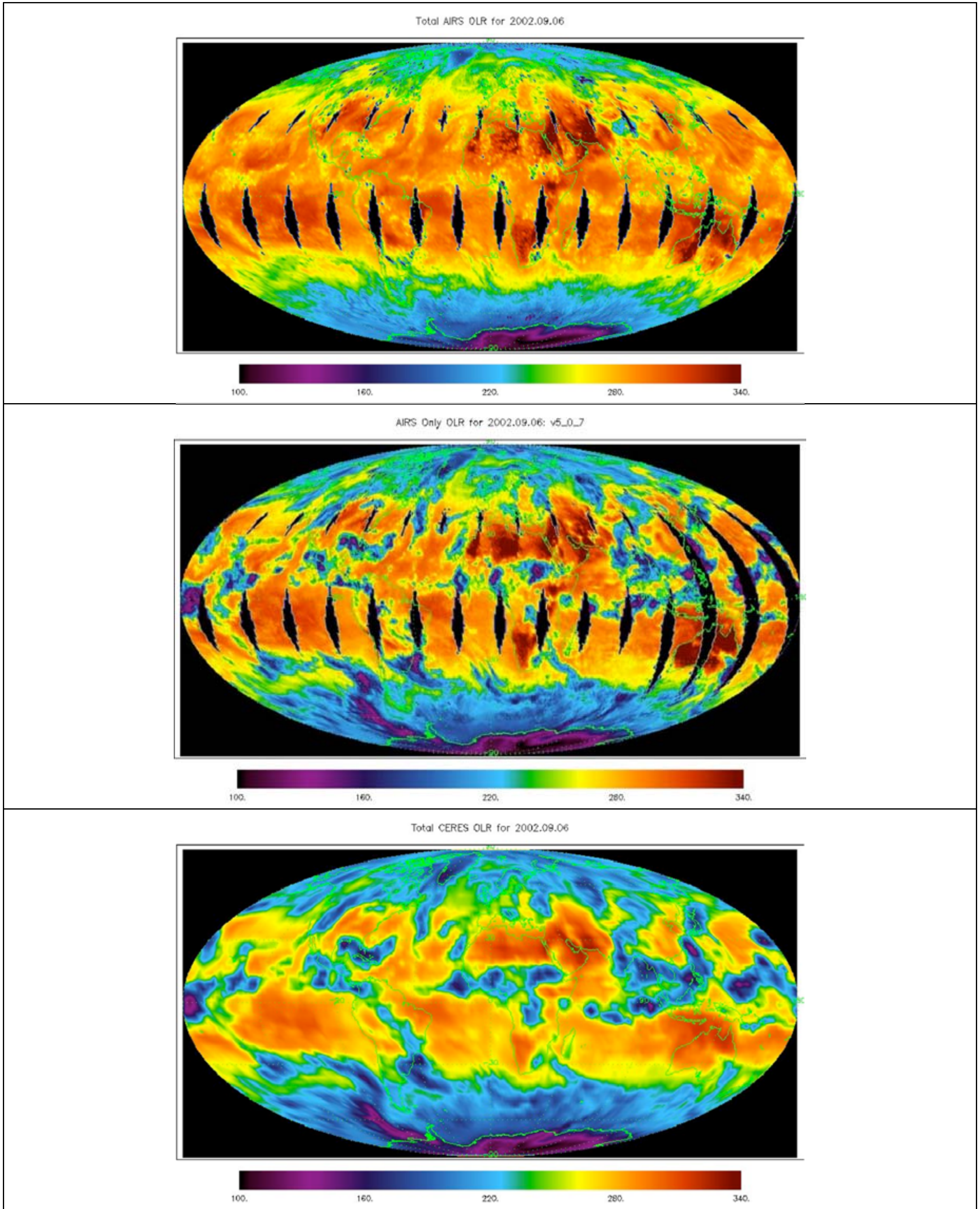

Figure 9: Global Distribution of OLR for Sept 6, 2002

Top panel: AIRS V4 with coding error corrected
Middle panel: AIRS V5
Bottom panel: Aqua CERES

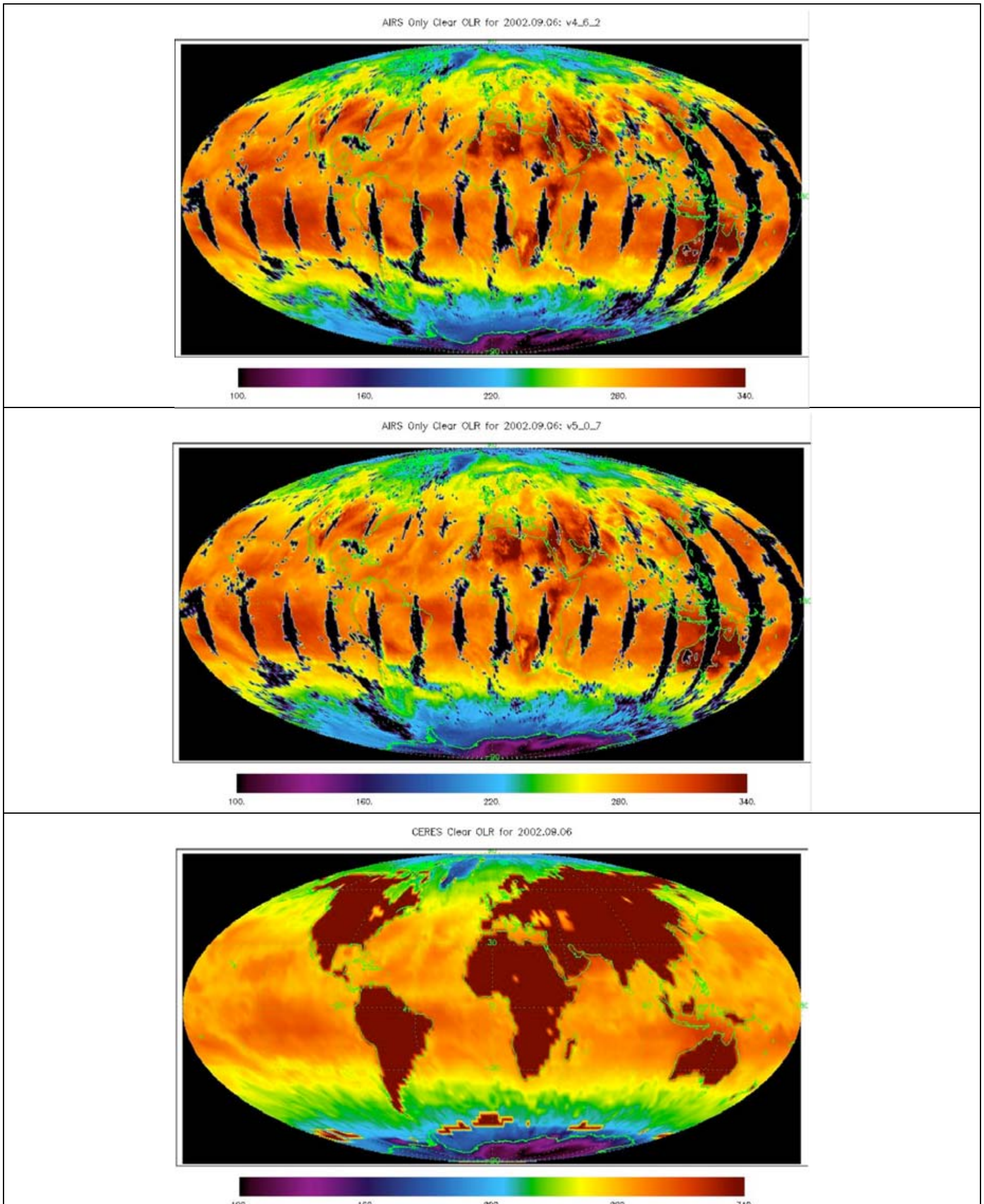

Figure 10: Global Distribution of Clear Sky OLR for Sept 6, 2002
Top panel: AIRS V4
Middle panel: AIRS V5
Bottom panel: Aqua CERES

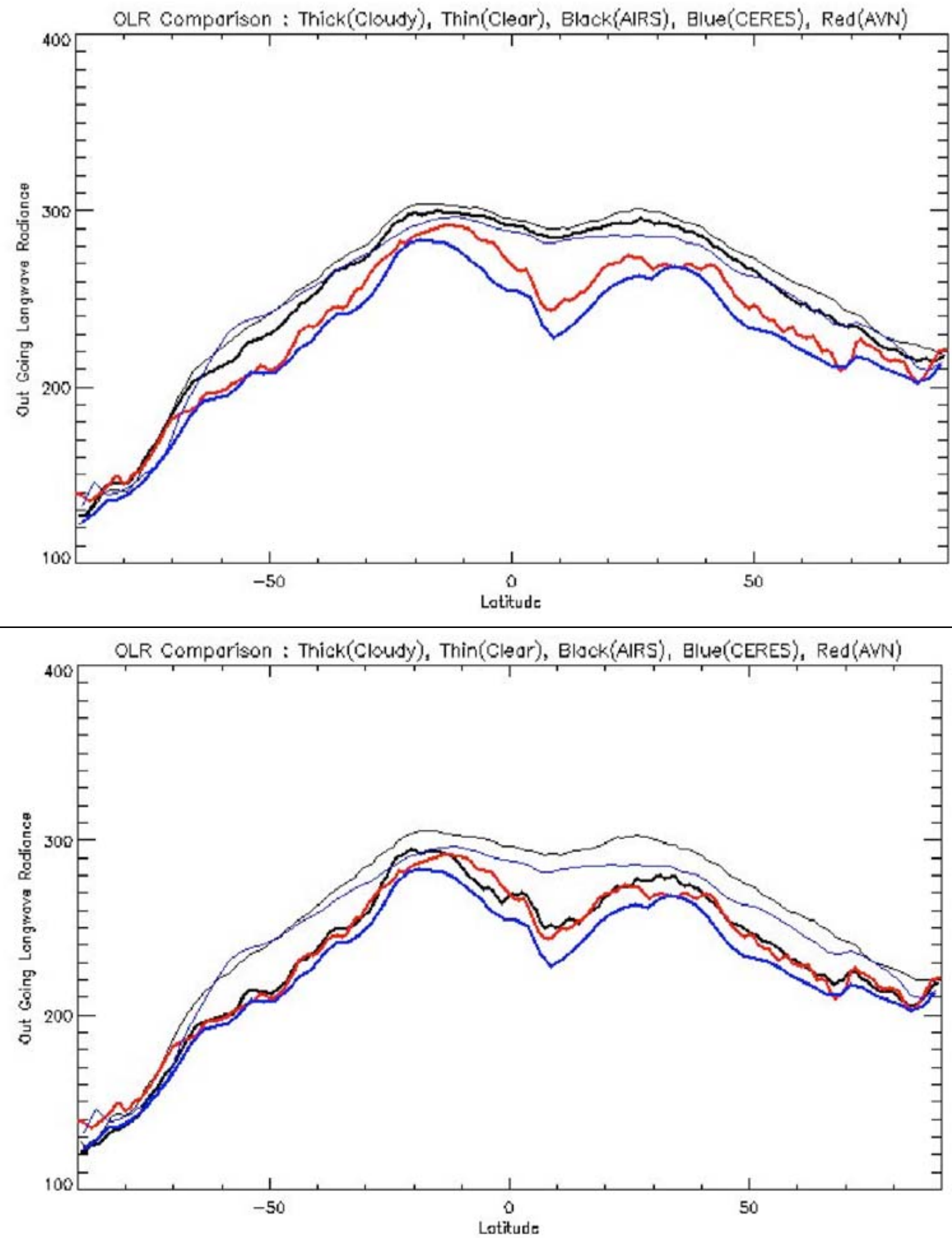

Figure 11: Zonal Average AIRS total OLR(thick black line), AIRS clear OLR (thin black line) compared to Aqua CERES (blue line) and AVN (red line)

Top panel: AIRS V4 (with coding error corrected)
Bottom panel: AIRS V5

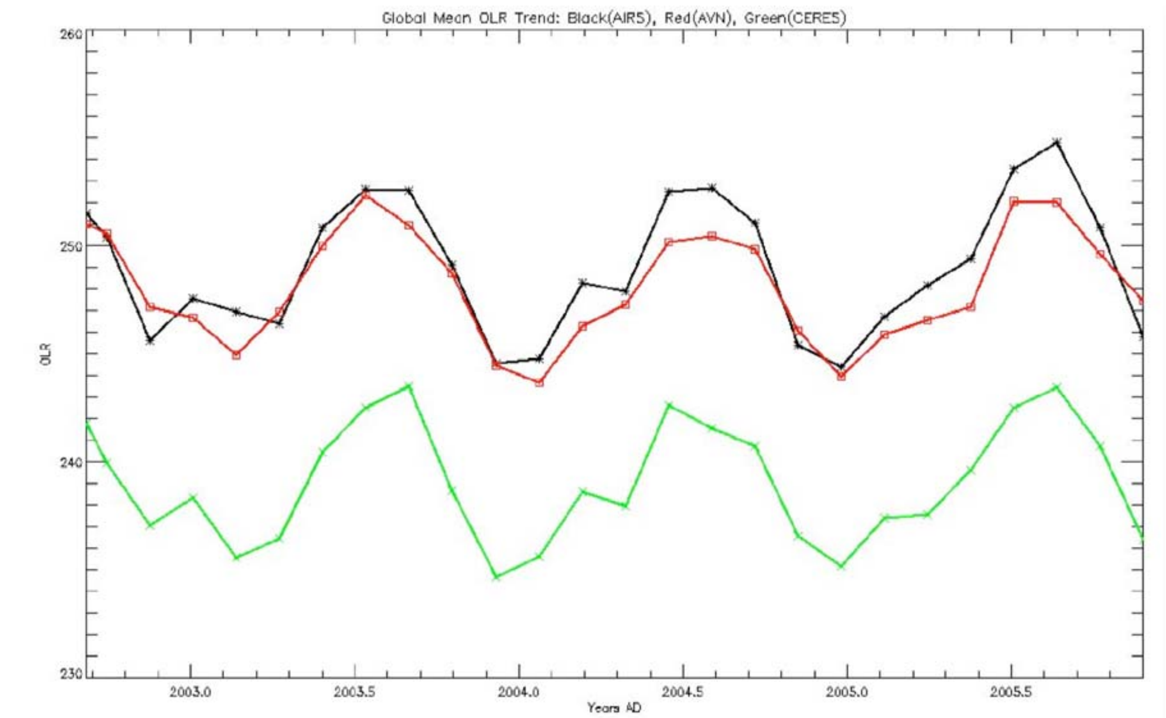

Figure 12: Global mean total OLR trend over three years of AIRS 48-day focus days

Black curve: V5 AIRS, averaging ascending and descending data
Red curve: NCEP AVN OLR calculated from 3 hr forecast for each focus day
Green curve:Aqua CERES OLR product for each focus day
Vertical axis units is W/m^2.
There is very good agreement between AIRS and AVN, but a nearly constant 10 W/m^2 bias with respect to Aqua CERES. The bias may be attributed to the outdated forward model AIRS uses as well as a slight difference in the definition of OLR. AIRS is the average of 1:30 AM and 1:30 PM local time OLR, whereas Aqua CERES values represent the daily mean OLR.

Quality Indicators

Qual_Cloud_OLR – overall quality indicator for cloud parameters and cloudy OLR

0 = best, judged suitable for assimilation and statistical climate studies
(final IR retrieval)

1 = good, judged suitable for statistical climate studies
(fallback retrieval)
CAUTION: In this case the average cloud fraction over the 9 AIRS spots is reported, duplicated 9 times for each cloud layer

2 = do not use, cloud retrieval did not complete

all_spots_avg – indicates whether cloud clearing was applied

0 = cloud clearing was applied

1 = scene was judged sufficiently clear by cloud clearing algorithm that no cloud clearing was applied and the radiances from all AIRS spots were averaged for use in subsequent retrieval steps. In this case, CldFrcStd should be identically zero.

-1 or 255 = cloud clearing not attempted

Initial_CC_score – indicates how well initial cloud cleared radiances can be reconstructed from eigenvectors

=0.33 = best possible result, a 3X reduction in noise

< 0.8 = a very good match

< 3.0 = a pretty good match

> 10.0 = a major problem encountered

Qual_clrolr – quality indicator for clear sky outgoing longwave radiation

0 = best, judged suitable for assimilation and statistical climate studies
(final IR retrieval and **totH2OstdErr**/**totH2Ostd** < 0.35)

2 = do not use

spectral_clear_indicator – flag for each of the 3x3 AIRS spots in an AMSU FOV indicating whether the spot was judged as clear by a spectral filter. Only validated over ocean. Values are

2 = ocean test applied and scene identified as clear

1 = ocean test applied and scene identified as not clear

0 = calculation could not be completed, possibly some inputs are missing or the scene is on a coasline or the edge of a scan or a granule

-1 = unvalidated land test applied and scene not identified as clear

-2 = unvalidated land test applied and scene identified as clear

NOTE: The algorithm that sets **spectral_clear_indicator** is a separate and significantly different measure of scene clarity than the algorithms that set **all_spots_avg** and **CldFrcStd**. We do not expect that when **spectral_clear_indicator** = 2 (ocean, clear) or -2 (land, clear) then the associated fields of **CldFrcStd** will be set = 0. Conversely, we do not expect that when **all_spots_avg** = 1 then the 9 fields of **spectral_clear_indicator** will be set to 2 (if ocean scene) or -2 (if land scene).

CAUTION: **num_clear_spectral_indicator** provides the number of AIRS spots in an AMSU FOV that have been judged clear, but it includes land as well as ocean scene spots in its report.

Caveats

Utilize **spectral_clear_indicator** only over ocean(i.e., **landFrac** = 0.0). The land algorithm has not yet been validated.

Cloud Product

Cloud top pressure can be stuck at round numbers of the form 25.00 * n in [125.00, 925.00]. The most common value is 300.00. A total of 1/3% to 2% of all successful cloud retrievals (Qual_Cloud_OLR = 0) give such round values

A small number of cases have round values for (PSurfStd – PcldTopStd). Values are {100.00, 175.00, 250.00, 325.00}

¼% to ½% of individual values of cloud fraction per layer per IR FOV have round values in {0.25000, 0.375000, 0.50000, 0.62500, 0.75000}. 0.50000 is the most common.

It has been shown that the higher quality retrievals for **TAirStd** and **H2OMMRStd** do not correspond to higher quality retrievals of cloud fields [Kahn et al. 2007a], and in fact, may have opposite tendencies. This is not unexpected as a stronger cloud radiative signature is associated with a more accurate cloud temperature, pressure, and amount. Thus, scenes in which it is more difficult to retrieve **TAirStd** and **H2OMMRStd** contain more accurate cloud retrievals and are associated with smaller uncertainties [see Kahn et al. 2007a,b].

The cloud retrievals assume spectral unit emissivity and only two layers are considered in the retrieval. Recent work on the sensitivity of cloud fields to assumptions of CO_2 show that spurious clouds arise from the treatment of CO_2 in the AIRS algorithm [Hearty et al. 2006]. Furthermore, if a cloud top pressure is retrieved above the tropopause it is readjusted to the tropopause level. There are additional caveats, further discussed in Kahn et al. [2007a,b]. Validation efforts and scientific applications may be found in the references. Please refer to these publications for detailed discussion.

OLR Product

No caveats as of this writing.

Suggestions for Researchers

Cloud Product

Please refer to the publications below for validation and application of AIRS cloud fields in scientific analyses. In *Kahn et al*. [2007a] AIRS cloud top height (derived from cloud top pressure and TAirStd) is compared to Atmospheric Radiation Measurement (ARM) program millimeter-wave cloud radar and micropulse lidar observations of clouds coincident with EOS Aqua, as well as the Microwave Limb Sounder observations of thin tropopause-level cirrus clouds. *Kahn et al.* [2007b] comprehensively compare MODIS and AIRS operational cloud retrievals, including cloud top temperature and effective cloud fraction as a function of cloud and scene type. It is shown that AIRS is better able to capture thin cirrus clouds than the operational MODIS algorithm, although there are other instances in which MODIS may outperform AIRS.

Kahn et al. [2007c] validates the AIRS cloud fields as a function of cloud type as determined by CloudSat and CALIPSO. AIRS agrees somewhat better in these cases than with the ARM measurements, which highlights respective sensitivities to cloud tops between surface- and space-based measurements. In *Kahn et al*. [2007d] we demonstrate the application of AIRS cloud fields in deriving optical and microphysical properties of thin cirrus. The thin cirrus properties in turn are related to AIRS relative humidity fields and demonstrate the power of AIRS to observe multiple fields simultaneously. Lastly, the fast radiative transfer model used to derive cirrus properties from AIRS radiances is discussed in *Yue et al*. [2007].

Many other research efforts are ongoing, with publications in preparation, in peer review, or in press. The researcher is recommended to review these (and other) AIRS-related publications, and to contact any of the authors of these publications to answer further inquiries. Brian Kahn, who has headed the balance of the AIRS cloud validation efforts, can be contacted at **brian.h.kahn@jpl.nasa.gov**.

OLR Product

A significant coding error was present in the V4 calculation of outgoing longwave radiation, **olr**, which resulted in overestimating it when high clouds were present in the scene, especially near the ITCZ. The clear sky outgoing longwave radiation, **clrolr**, was not affected by this error. The coding error has been corrected in V5.

Recommended Papers

Hearty, T.J., B.H. Kahn, and E. Fishbein (2006): Layer trends in Earth’s cloud cover, Fall Meeting American Geophysical Union, Poster number 5337–A26.

Kahn, B. H., Eldering, A., Braverman, A.J., Fetzer, E.J., Jiang, J.H., Fishbein, E., and Wu, D.L. (2007a): Toward the characterization of upper tropospheric clouds using Atmospheric Infrared Sounder and Microwave Limb Sounder observations, J. Geophys. Res., 112, D05202, doi:10.1029/2006JD007336.

Kahn, B. H., E. Fishbein, S. L. Nasiri, A. Eldering, E. J. Fetzer, M. J. Garay, and S.-Y. Lee (2007b), The radiative consistency of Atmospheric Infrared Sounder and Moderate Resolution Imaging Spectroradiometer cloud retrievals, J. Geophys. Res., 112, D09201, doi:10.1029/2006JD007486.

Kahn, B.H., M.T. Chahine, G.L. Stephens, G.G. Mace, R.T. Marchand, Z. Wang, A. Eldering, R.E. Holz, R.E. Kuehn, and C.D. Barnet (2007c): Cloud-type comparisons of AIRS, CloudSat, and CALIPSO cloud height and amount, Atmos. Chem. Phys., to be submitted.

Kahn, B.H., C. Liang, A. Eldering, A. Gettelman, K.-N. Liou, and Q. Yue (2007d): Tropical thin cirrus and relative humidity distributions simultaneously observed by AIRS, Atmos. Chem. Phys., to be submitted.

Mace, G. G., R. Marchand, Q. Zhang, and G. Stephens (2007), Global hydrometeor occurrence as observed by CloudSat: Initial observations from summer 2006, Geophys. Res. Lett., 34, L09808, doi:10.1029/2006GL029017

Mehta, A. and J. Susskind (1999), JGR volume 104, number D10, 12193-12212.

NASA Technical Report GSFC/CR-1999-208643

Yue, Q., Liou, K.N., Ou, S.C., Kahn, B.H., Yang, P., and Mace, G.G. (2007): Interpretation of AIRS data in thin cirrus atmospheres based on a fast radiative transfer model, *J. Atmos. Sci*., in press.

Recommended Supplemental User Documentation

V5_L2_Standard_Pressure_Levels.pdf

V5_L2_Quality_Control_and_Error_Estimation.pdf

V5_CalVal_Status_Summary.pdf

V5_Retrieval_Channel_Sets.pdf

V5_Retrieval_Flow.pdf

AIRS Standard Carbon Monoxide Product

Field Name	Dimension per FOV	Description
CO_first_guess	8-character string	Name of CO First Guess source
CO_trapezoid_layers	COFunc=9	1-based Index of **pressSup** array giving element defining lower altitude bound of trapezoid on which the CO variables are defined, (unitless)
CO_eff_press	COFunc=9	CO effective pressure for the center of each trapezoid. These CO trapezoids were chosen to approximately match MOPITT standard levels, (mb)
CO_VMR_eff	COFunc=9	Effective CO Volume Mixing Ratio Profile (vmr) for each trapezoid, (unitless)
CO_VMR_eff_err	COFunc=9	Error estimate (vmr), (unitless)
CO_total_column	1	Retrieved total column CO, (molecules/cm^2)
num_CO_Func	1	Number of valid entries in each dimension of CO_ave_kern
CO_verticality	COFunc=9	Sum of rows of CO_ave_kern, (unitless)
CO_Resid_Ratio	1	Internal retrieval quality indicator; residuals of CO channels as compared to predicted uncertainty, (unitless)
CO_dof	1	Degrees of freedom, measure of amount of information in CO retrieval, (unitless)

Description

The AIRS standard carbon monoxide product is a product of the IR stage of the combined IR/MW retrieval. **CO_VMR_eff** is the retrieved volume mixing ratio (ratio of number of CO molecules to the number of molecules of air in a unit volume) for a layer defined by the faces of a CO trapezoidal retrieval function (see **V5_L2_Levels_Layers_Trapezoids.pdf**). The boundaries of the faces of these layers are specified in **CO_trapezoid_layers** in which is an array of 1-based **pressSup** level indices (see **V5_L2_Support_Pressure_Levels.pdf**).

In V5, there are 9 such layers corresponding to the 9 trapezoidal retrieval functions utilized for CO, which are illustrated in the following figure. Note that the sides of the trapezoids drop off from the face linearly in log(p), dropping to zero at the level of the most distant vertex of the adjacent trapezoid face. The lowest altitude trapezoid drop off terminates at the surface and the highest altitude trapezoid drop off terminates at the TOA.

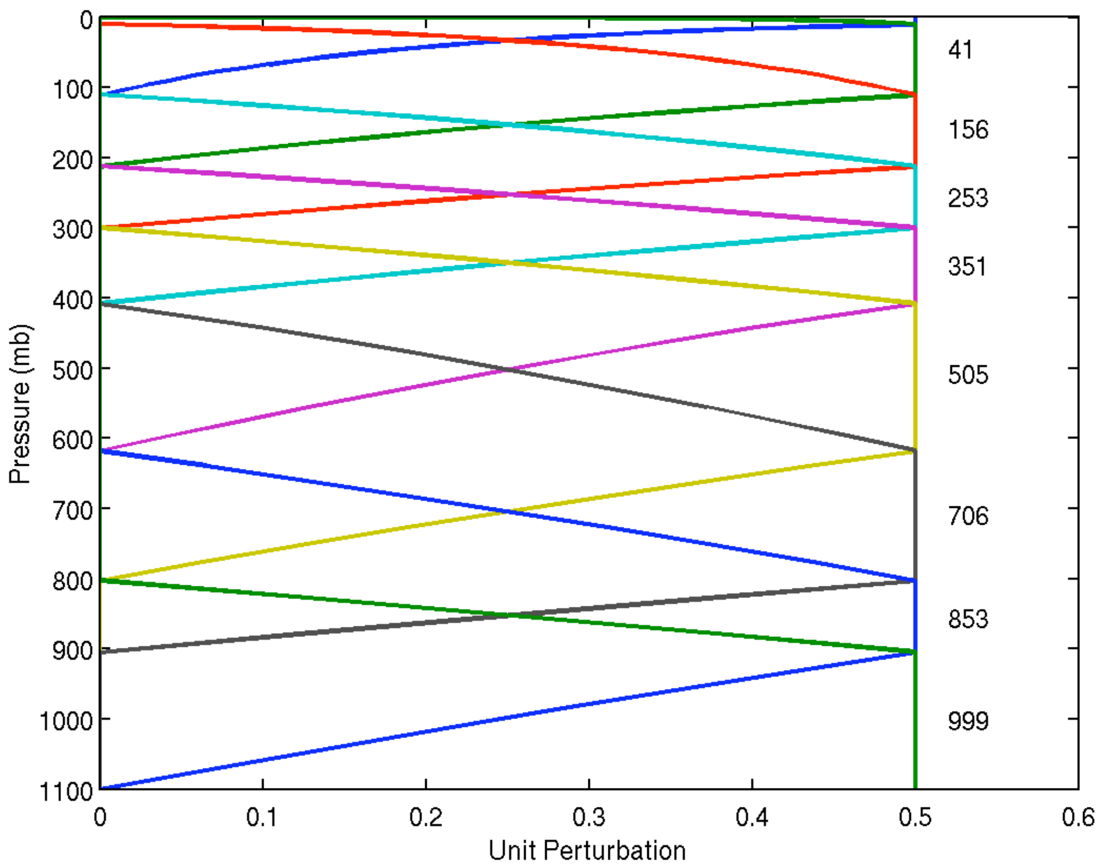

Figure 13: The 9 CO trapezoids.
Values at right are **CO_eff_press** for each. (Wallace McMillan)

CO_eff_press is defined as the pressure weighted center of the trapezoid layers, i.e.,

$$\text{CO\_eff\_press} = \frac{\left[P_{bottom} - P_{top}\right]}{\log\left(P_{bottom}/P_{top}\right)}$$

where P_{bottom} is the bottom pressure of a trapezoid face and P_{top} is the top pressure. These trapezoid layers were chosen so that the **CO_eff_press** match as closely as possible to the standard pressure levels used by MOPITT and to optimize the AIRS CO retrieval.

CO_VMR_eff is computed from the integrated CO column density for the trapezoidal layer, and is reported at the effective pressure, **CO_eff_press**, of the layer. **CO_eff_press** is defined as the pressure weighted center of the layer and the values have been defined to match those of MOPITT. Layers below the surface are filled with -9999. The value quoted on the lowest layer above the surface is the mean volume mixing ratio in the layer bounded by the next higher level and the surface.

CO_VMR_eff_err is the estimated error in CO mixing ratio due to the retrieved errors in temperature, water vapor and surface temperature as derived by Comer (2006). This error is computed on the **pressSup** layers and then averaged to the CO trapezoids.

CO_total_column is the integrated column amount of CO from the top of the atmosphere (TOA = 0.005 mb) to the surface. This quantity is computed by summing the 100 column density values, **COCDsup,** contained in the AIRS level 2 Support Products file with the appropriate weighting applied to the bottom layer which contains the surface. Layers below the surface are not included in this sum.

CO_dof provides a measure of the amount of information in the carbon monoxide retrieval. It is computed by summing the diagonal elements of the 9x9 CO averaging kernel, **CO_avg_kern**, stored in the AIRS Support Product files. Validation and optimization studies (Comer, 2006) have shown **CO_dof** < 0.4 indicates little information in the retrieval comes from the measured radiances. Profiles for which 0.5 > **CO_dof** > 0.4 should be used with great caution.

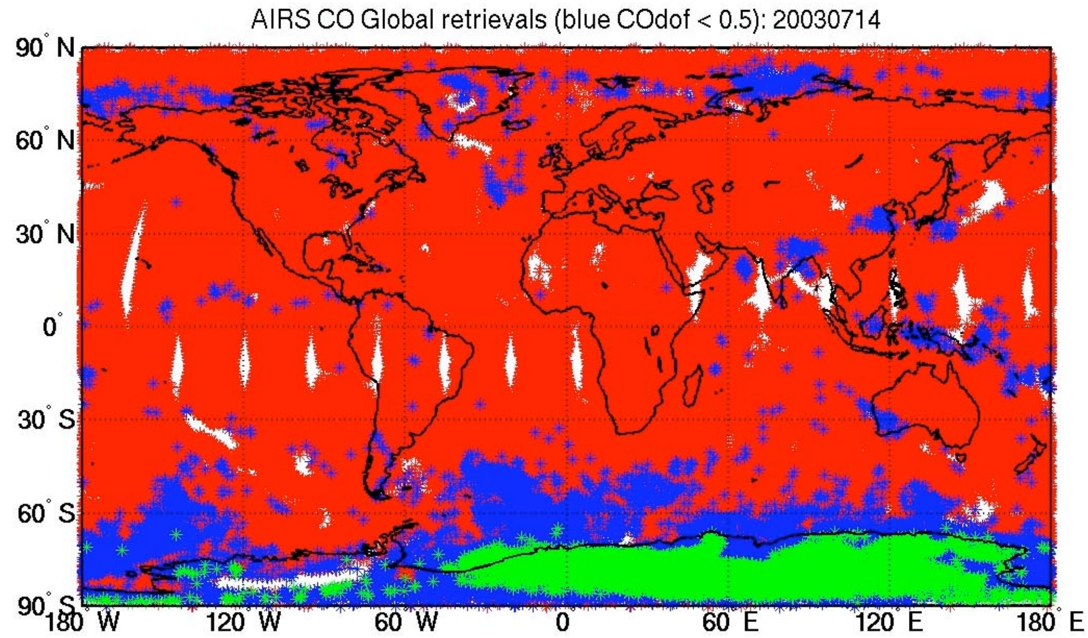

Figure 14: Global distribution of CO_dof for test V5.0.7 on July 14, 2003 (Wallace McMillan)

CO_dof > 0.5 CO_dof < 0.5 CO_dof < 0.4

CO_verticality is a 9 point vector computed by summing the columns of the 9x9 CO averaging kernel, **CO_avg_kern**, stored in the AIRS Level 2 Support Product. The peak of **CO_verticality** indicates the vertical location of the maximum sensitivity of the CO product and the magnitudes of **CO_verticality** are a rough measure of the fraction of the retrieval determined from the data as opposed to the first guess. Values near unity should be considered highly determined from the measurement, while smaller values indicate the retrieval contains a large fraction of the first guess.

NOTE: the problem with associating the verticality with a total column averaging kernel is that it neglects the fact that the retrieval can only move as superpositions of the trapezoids. Convolution using the verticality alone will not account for the possibility that the "independent CO profile" contains structure that the trapezoids can or cannot resolve.

Type of Product

The standard CO product profile is a layer quantities, i.e. the values are reported on the pressure levels but represent the layer bounded by the level on which they are reported and the next higher level (in altitude). In this case, the layers are the **CO_trapezoid_layers**.

For more detail, see **V5_L2_Levels_Layers_Trapezoids.pdf** for a full discussion of level and layer quantities.

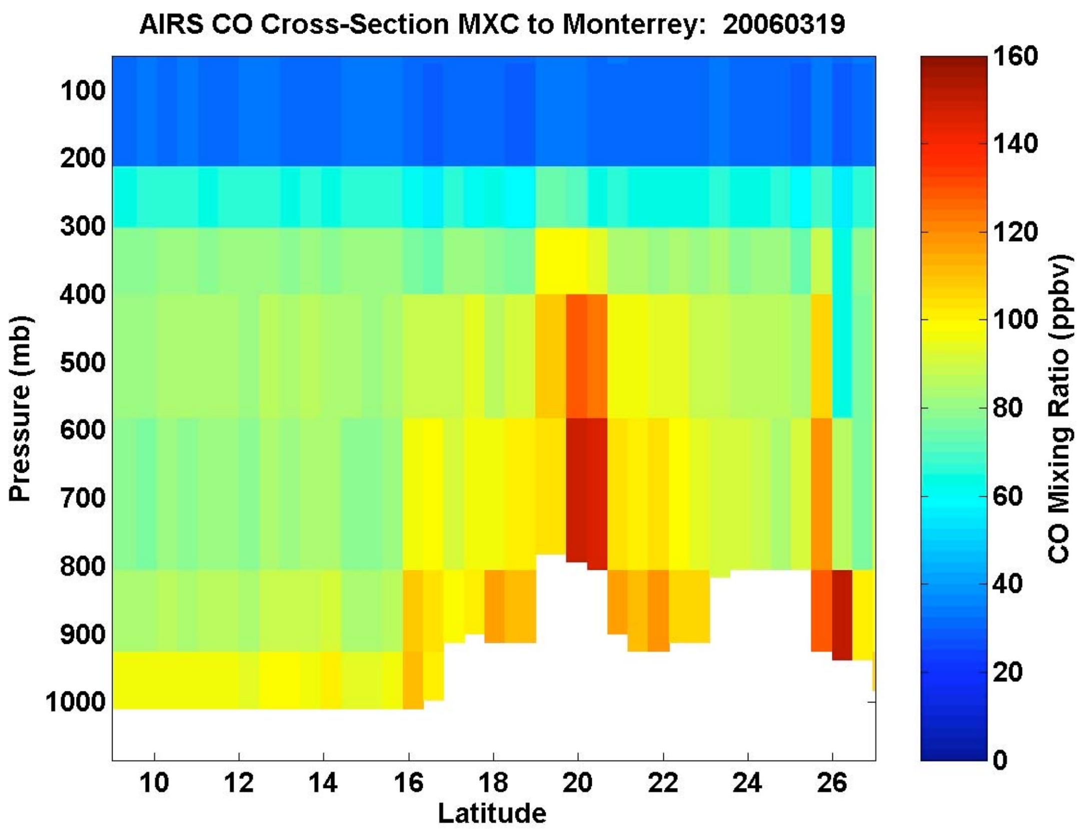

Figure 15: Example CO_VMR_eff profiles for transect Mexico City to Monterrey showing the CO plumes from both. (Wallace McMillan)

Quality Indicators

Qual_CO – pertains to the entire **CO_VMR_eff** profile and **CO_total_column**

- 0 = best, CO product judged suitable for assimilation
  (final IR retrieval and **totH2OstdErr**/**totH2Ostd** < 0.35
  and **CO_dof** > 0.5)
- 1 = use with caution; less than half the retrieval results
  from the measured radiances
  (final IR retrieval and **totH2OstdErr**/**totH2Ostd** < 0.35
  and 0.5 ≥ **CO_dof** > 0.4)
- 2 = do not use

Caveats

Qual_CO is set to 0 if **totH2OstdErr/totH2OStd** ≤ 0.35 and the final IR retrieval is the atmospheric state of the reported products and **CO_dof** > 0.5.

Suggestions for Researchers

AIRS V5 CO retrievals are provisionally validated. We are still assessing the derived error fields for quality control, but have erred on the conservative side to provide the best possible data.

We recommend that researchers pre-filter retrievals by requiring

(**PsurfStd** – **PBest**) < 200 mb

and then filtering further by requiring **Qual_CO** = 0.

We strongly urge caution in using any retrievals for which **Qual_CO** > 0. We suggest that trapezoids for which **CO_VMR_eff_err** is negative or greater than 50% of **CO_VMR_eff** should be excised.

Recommended Papers

Comer, M.M. (2006), Retrieving Carbon Monoxide Abundances from the Atmospheric Infrared Sound, PhD dissertation, Department of Physics, University of Maryland Baltimore County.

Freitas S. R., K. M. Longo, M. O. Andreae (2006), Impact of including the plume rise of vegetation fires in numerical simulations of associated atmospheric pollutants, Geophys. Res. Lett., 33, L17808, doi:10.1029/2006GL026608.

McMillan W. W., C. Barnet, L. Strow, M. T. Chahine, M. L. McCourt, J. X. Warner, P. C. Novelli, S. Korontzi, E. S. Maddy, S. Datta (2005), "Daily global maps of carbon monoxide from NASA's Atmospheric Infrared Sounder", Geophys. Res. Lett., 32, L11801, doi:10.1029/2004GL021821.

Warner, J., M. M. Comer, C. D. Barnet, W. W. McMillan, W. Wolf, E. Maddy, and G. Sachse (2007), A comparison of satellite tropospheric carbon monoxide measurements from AIRS and MOPITT during INTEX-A, J. Geophys. Res., 112, D12S17, doi:10.1029/2006JD007925

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V5_Retrieval_Flow.pdf

AIRS Standard Methane Product

Field Name	Dimension per FOV	Description
CH4_first_guess	8-character string	Name of CH4 First Guess source
CH4_trapezoid_layers	CH4Func=7	1-based Index of **pressSup** array giving element defining lower altitude bound of trapezoid on which the CH4 variables are defined, (unitless)
CH4_eff_press	CH4Func=7	CH4 effective pressure for the center of each trapezoid, (mb)
CH4_VMR_eff	CH4Func=7	Effective CH4 Volume Mixing Ratio Profile (vmr) for each trapezoid, (unitless)
CH4_VMR_eff_err	CH4Func=7	Error estimate (vmr), (unitless)
CH4_total_column	1	Retrieved total column CH4, (molecules/cm^2)
num_CH4_Func	1	Number of valid entries in each dimension of CH4_ave_kern
CH4_verticality	CH4Func=7	Sum of rows of O3_ave_kern, (unitless)
CH4_Resid_Ratio	1	Internal retrieval quality indicator; residuals of CH4 channels as compared to predicted uncertainty, (unitless)
CH4_dof	1	Degrees of freedom, measure of amount of information in CH4 retrieval, (unitless)

Description

The AIRS standard methane product is a product of the IR stage of the combined IR/MW retrieval. **CH4_VMR_eff** is the retrieved volume mixing ratio (ratio of number of CH_4 molecules to the number of molecules of air in a unit volume) for a layer defined by the faces of a CH_4 trapezoidal retrieval function. The boundaries of these layers are specified in **CH4_trapezoid_layers** in terms of the 100-level AIRS support pressure array (see **V5_L2_Support_Pressure_Levels.pdf**). In V5, there are 9 such layers corresponding to the 9 trapezoidal retrieval functions utilized for CH_4. **CH4_VMR_eff** is computed from the integrated CH4 column density for the trapezoidal layer, and is reported at the effective pressure, **CH4_eff_press**, of the layer. **CH4_eff_press** is defined as the pressure weighted center of the layer. Layers below the surface are filled with -9999. The value quoted on the lowest layer above the surface is the mean mixing ratio in the layer bounded by the next higher level and the surface.

CH4_eff_press is defined as the pressure weighted center of the trapezoid layers, i.e.,

$$\text{CH4\_eff\_press} = \frac{\left[P_{bottom} - P_{top}\right]}{\log\left(P_{bottom} / P_{top}\right)}$$

where P_{bottom} is the bottom pressure of a trapezoid face and P_{top} is the top oressure.

CH4_VMR_eff_err is the estimated error in CH_4 mixing ratio due to the retrieved errors in temperature, water vapor and surface temperature as derived by Comer (2006). This error is computed on the **pressSup** layers and then averaged to the CH_4 trapezoids.

CH4_total_column is the integrated column amount of CH_4 from the top of the atmosphere (TOA = 0.005 mb) to the surface. This quantity is computed by summing the 100 column density values, **CH4CDsup,** contained in the AIRS level 2 Support Products file with the appropriate weighting applied to the bottom layer which contains the surface. Layers below the surface are not included in this sum.

CH4_dof provides a measure of the amount of information in the carbon monoxide retrieval. It is computed by summing the diagonal elements of the 9x9 CH_4 averaging kernel, **CH4_avg_kern**, stored in the AIRS Support Product files.

CH4_verticality is a 9 point vector computed by summing the columns of the 9x9 CH_4 averaging kernel, **CH4_avg_kern**, stored in the AIRS Level 2 Support Product. The peak of **CH4_verticality** indicates the vertical location of the maximum sensitivity of the CH_4 product and the magnitudes of **CH4_verticality** are a rough measure of the fraction of the retrieval determined from the data as opposed to the first guess. Values near unity should be considered highly determined from the measurement, while smaller values indicate the retrieval contains a large fraction of the first guess.

NOTE: the problem with associating the verticality with a total column averaging kernel is that it neglects the fact that the retrieval can only move as superpositions of the trapezoids. Convolution using the verticality alone will not account for the possibility that the "independent CH_4 profile" contains structure that the trapezoids can or cannot resolve.

Type of Product

The standard CH_4 product profile is a layer quantities, i.e. the values are reported on the pressure levels but represent the layer bounded by the level on which they are reported and the next higher level (in altitude). In this case, the layers are the **CH4_trapezoid_layers**.

For more detail, see **V5_L2_Levels_Layers_Trapezoids.pdf** for a full discussion of level and layer quantities.

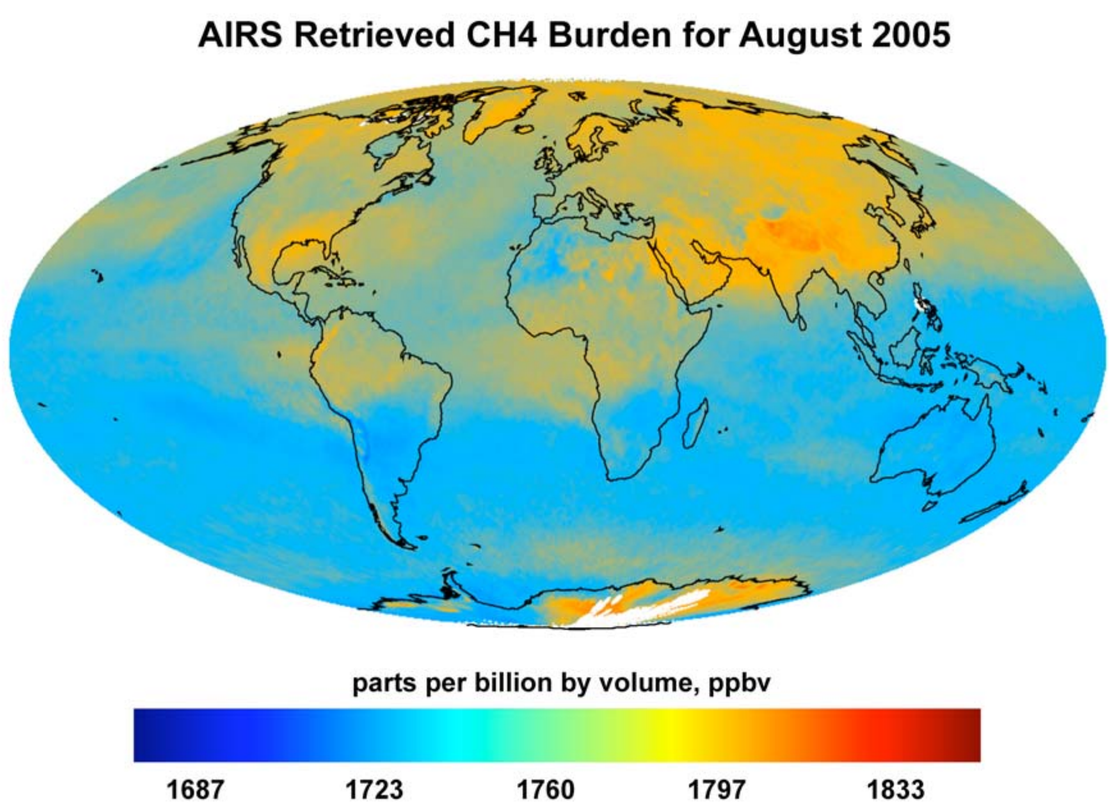

Figure 16: AIRS V5 CH4_total_column averaged over month of August, 2005.

See discussion in Caveats and Suggestions for Researchers

Quality Indicators

Qual_CH4 – pertains to the entire **CH4_VMR_eff** profile and **CH4_total_column**

0 = best, CH_4 product judged suitable for assimilation
(final IR retrieval and **totH2OstdErr/totH2Ostd** < 0.35
and **CH4_dof** > 0.5)

1 = use with caution; less than half the retrieval results
from the measured radiances
(final IR retrieval and **totH2OstdErr/totH2Ostd** < 0.35
and 0.5 ≥ **CH4_dof** > 0.4)

2 = do not use

Caveats

CH_4 retrieval is based on the AIRS retrieved atmospheric temperature and water moisture profiles, and surface temperature and emissivity, so uncertainty of these variables and errors in cloud/clearing and RTA will significantly impact the accuracy of the retrieved CH_4. For example, a higher CH_4 over the tropical ocean than that over the South America may be due to the error in cloud clearing.

Damping the retrieval to make it less sensitive to noise and interfering species (e.g., errors in water and temperature profile) is a basic concept in CH_4 retrieval. However, information content will vary for different atmospheric states and will vary as a function of cloudiness, latitude, and moisture content. A uniform damping threshold is used for all cases; however, we have found that the retrievals may be under-damped in polar regions due to poor propagation of internal error estimates. Hence, problems still exist in polar regions and at high altitudes.

The most sensitive region of AIRS to atmospheric CH_4 is in the middle to upper troposphere, and its sensitive to CH_4 in the lower atmosphere is very low, especially in the tropical region. For this reason, averaging kernels must be utilized in any comparison of AIRS CH_4 with in-situ observation and/or model data. Also, it should be noted that the retrieved CH_4 mixing ratios in different layers are not independent, and the total amount calculated by adding up the retrieved CH_4 for all the separate layers may not equal to the total burden in the atmosphere. To recalculate the total CH_4 , users must use the layer column densities (**CH4CDSup**) in the support product.

An appropriate first-guess (or a priori) that represents the climatology is required as in the retrieval. Our knowledge of CH_4 distribution in the upper troposphere and stratosphere is limited, even though we have HALOE observations. Thus the uncertainty in these regions is larger than that in the lower troposphere where we have ground-based and aircraft observations. Hence, the first-guess of CH_4 in the upper troposphere and stratosphere may be poor. There is not enough observational data available for us to validate AIRS CH_4 in that region at this time.

Interference from HNO_3 has not been taken into account in V5. If there is significant variability in HNO_3 the CH_4 product may be in error. This issue will be studied and rectified, if necessary, in V6.

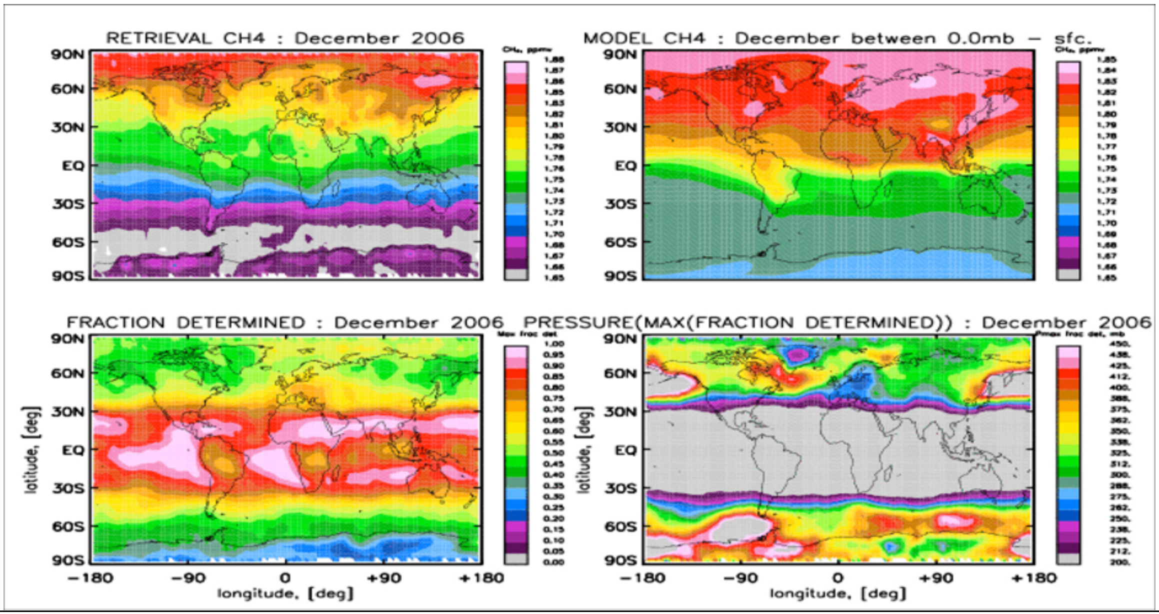

Figure 17: AIRS V5 CH4 retrieval (Chris Barnet, NOAA) compared to model total burden for December, 2006 (model by Sander Houweling, SRON)

Top left panel: AIRS mid-tropospheric CH4 column, ppmv
Top right panel: model total column burden, ppmv
Bottom left panel: fraction of AIRS CH4 determined from AIRS radiances
Bottom right panel: pressure of AIRS peak sensitivity, mb

Suggestions for Researchers

Given all of issues described in the caveats, we caution researchers to consider the V5 CH_4 product to be a provisional release. It is an exploratory product and we had to modify the climatology and RTA shortly before delivery to take into account the recently re-released NOAA ESRL measurements in the 400-500 mb region (with a +20 ppbv correction). The lack of sufficient QA or regularization of the retrieval makes the methane values in the tropics, deserts, and Antarctica suspicious. The **CH4_dof** test does not improve this in the tropical region.

We recommend that researchers only use profiles for which **Qual_CH4** = 0. We also recommend additional filtering through use of the estimated error, **CH4_VMR_eff_err**, to excise those profiles in which it is greater than 5% of **CH4_VMR_eff**. Finally, we recommend that researchers also filter profiles by requiring that **PBest** ≥ 750 mb. Improving the QA for the methane retrieval will be a major focus for V6.

Recommended Papers

Recommended Supplemental User Documentation

V5_L2_Standard_Pressure_Levels.pdf
V5_L2_Quality_Control_and_Error_Estimation.pdf
V5_CalVal_Status_Summary.pdf
V5_Retrieval_Channel_Sets.pdf
V5_Retrieval_Flow.pdf

AIRS Standard Sulfur Dioxide and Dust Product

Field Name	Dimension per FOV	Description
NumSO2FOVs	1	Number of FOVs (out of a nominal 1350) in granule with a significant SO_2 content based on the value of **BT_diff_SO2**, located in the L2 Support Product, (unitless)
Dust_flag	3x3	Flag indicating whether dust has been detected in each AIRS spot within an AMSU FOV. Set to 1 if dust has been detected; set to to 0 if dust has not been detected, (unitless)

Description

The detection of the presence of dust or volcanic SO2 is made by comparison of radiances, and the flags originate in the AIRS L1B Product. They are propagated to the Level 2 Standard and Support Products.

Data indicating which AMSU FOVs and which AIRS spots within the AMSU FOVs indicate the presence of excessive SO_2 are located in the AIRS Level 2 Support Product. The entry is **BT_diff_SO2** and it is a 3x3 array of brightness temperature differences for each AMSU FOV. The temperature difference tested is:

$$\Delta T_b = T_b\left(1361.44\ cm^{-1}\right) - T_b\left(1433.06\ cm^{-1}\right)$$

If $\Delta T_b < -6\ K$ the presence of volcanic SO_2 is highly likely.

Dust_flag – flag for each of the 3x3 AIRS spots in an AMSU FOV indicating whether dust was detected in the spot. Values are

1 = dust detected

0 = dust not detected

-1 = dust test not valid because of land

-2 = dust test not valid because of high latitude

-3 = dust test not valid because of suspected cloud

-4 = dust test not valid because of bad input data

Type of Product

The AIRS V5 SO_2 and Dust products are flags indicating the present or absence of a detection of these constituents. We expect them to be expanded to total burden in V6.

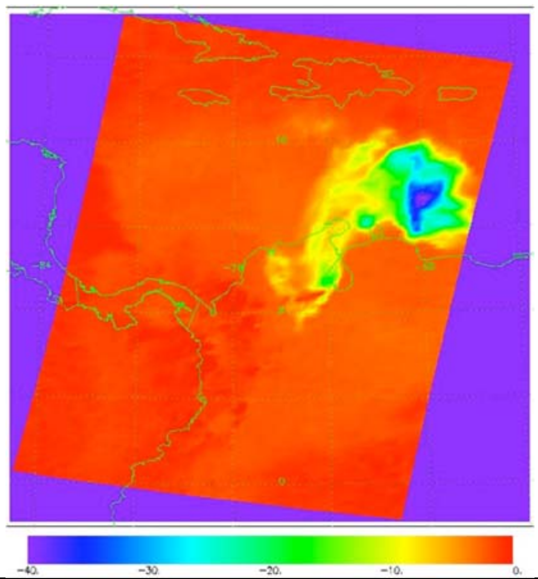

Figure 18: AIRS V5 SO2 ΔT_b on May 21, 2006.

Observation 24 hours after dome collapse of Soufrier Hills volcano in Montserrat.

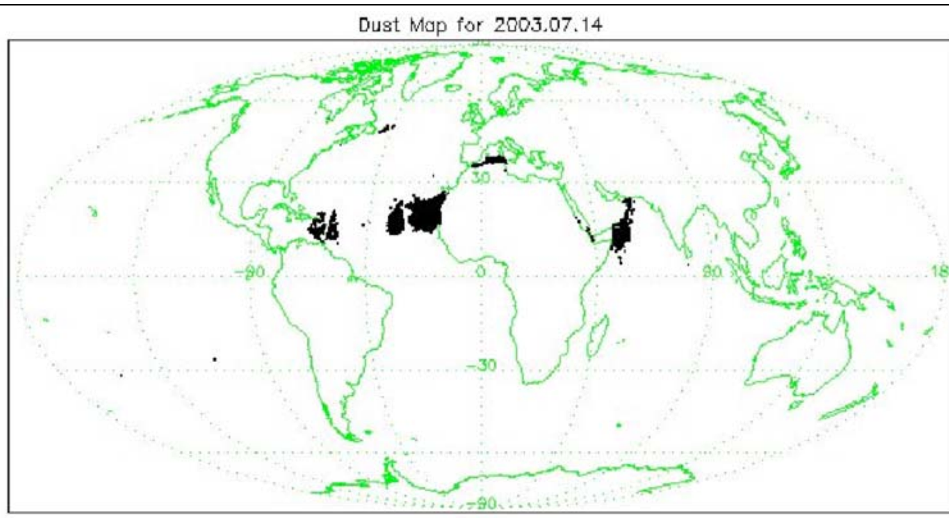

Figure 19: AIRS V5 global dust flag map for July 14, 2003

Quality Indicators

There are no quality indicators in V5.

Caveats

The dust flag is reliable only in an otherwise clear atmosphere over ocean. The algorithm fails if thin cirrus or other clouds are present above the dust.

Suggestions for Researchers

Recommended Papers

Carn S. A., L. L. Strow, S. de Souza-Machado, Y. Edmonds, S. Hannon (2005), Quantifying tropospheric volcanic emissions with AIRS: The 2002 eruption of Mt. Etna (Italy), Geophys. Res. Lett., 32, L02301, doi:10.1029/2004GL021034.

DeSouza-Machado, S. G., L. L. Strow, S. E. Hannon, and H. E. Motteler (2006), Infrared dust spectral signatures from AIRS, Geophys. Res. Lett., 33, L03801, doi:10.1029/2005GL024364.

Nalli N. R., et al. (2005), Profile observations of the Saharan air layer during AEROSE 2004, Geophys. Res. Lett., 32, L05815, doi:10.1029/2004GL022028.

Nalli N. R., et al. (2006), Ship-based measurements for infrared sensor validation during Aerosol and Ocean Science Expedition 2004, J. Geophys. Res., 111, D09S04, doi:10.1029/2005JD006385.

Pierangelo C., M. Mishchenko, Y. Balkanski, A. Chédin (2005), Retrieving the effective radius of Saharan dust coarse mode from AIRS, Geophys. Res. Lett., 32, L20813, doi:10.1029/2005GL023425.

Wong S., P. R. Colarco, A. E. Dessler (2006), Principal component analysis of the evolution of the Saharan air layer and dust transport: Comparisons between a model simulation and MODIS and AIRS retrievals, J. Geophys. Res., 111, D20109, doi:10.1029/2006JD007093.

Wright,R., Carn,S. A., Flynn,L. P. (2005), A satellite chronology of the May-June 2003 eruption of Anatahan volcano, Journal of Volcanology and Geothermal Research, 146, 102-116. doi: 10.1016/j.jvolgeores.2004.10.021

Recommended Supplemental User Documentation

V5_L2_Standard_Pressure_Levels.pdf

V5_L2_Quality_Control_and_Error_Estimation.pdf

V5_CalVal_Status_Summary.pdf

V5_Retrieval_Channel_Sets.pdf

V5_Retrieval_Flow.pdf