

AIRS/AMSU/HSB Version 5 Level 2 Quality Control and Error Estimation

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Level 2 Quality Indicators

Introduction

The AIRS Level 2 Standard Product contains many retrieved parameters, and each has an associated quality indicator which the researcher should use to filter and subset the specific geophysical parameter of interest. The possible values are:

Quality = 0 => “BEST”

Data products individually meet our accuracy requirements and may be used for data assimilation and statistical climate studies.

Quality = 1 => “GOOD”

Data may be used for statistical climate studies, as they meet the accuracy requirements only when temporally and/or spatially averaged. Note that relying solely on quality = 0 cases when generating monthly mean fields may result in significant sampling biases.

Quality = 2 => “DO NOT USE”

While we do not recommend use of any quality = 2 data, we recognize that it may be the only data available in the vicinity of hurricanes and storm fronts. Users should carefully check the error estimates on the individual soundings and proceed with great caution if they contemplate making use of these data.

We create our level 3 products by combining quality = 0 and quality = 1 data, averaged over the appropriate area and time period.

The legacy variable **RetQAFlag** is a concatenation of the limited quality information present in previous releases. Although it is still present in the V5 Level 2 Products we strongly recommend users avoid its use. This flag is not compatible with the expanded V5 release quality control.

A set of retrieved parameters is generated for each AMSU FOV. In most cases, complete soundings are produced using both AIRS and AMSU observations. In the event that satisfactory infrared cloud cleared radiances cannot be produced, all surface and atmospheric retrieval products are flagged quality = 2 (do not use). If clouds can be obtained from the startup state, the cloud related products including outgoing longwave radiation (OLR) and precipitation estimate are flagged quality = 1.

Whenever the IR/MW retrieval is completed, clouds are computed from that state and flagged quality = 0. The surface and atmospheric retrieval products are then flagged with the following quality indicators. More details of the algorithmic flow can be found in the document **V5_L2_Retrieval_Flow.pdf**.

Level 2 MW-Only Retrieval Quality Indicators

MW-Only Temperature Profile 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 ($> 0.5 \text{ kg/m}^2$)
- 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

MW-Only Moisture Profile and Cloud Liquid Water Quality Indicator

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

Level 2 Combined IR/MW Retrieval Quality Indicators

Temperature Profile Quality Indicators

V5 introduces two characteristic pressures which define the quality of the temperature profile of an accepted IR/MW retrieval:

- **PBest** The **TAirStd** temperature profile from the top of the atmosphere to this pressure level is of best quality (i.e., quality = 0).
- **PGood** The **TAirStd** temperature profile below the level of **PBest** down to this pressure level is of good quality (i.e., quality = 1). The temperature profile below the level of **PGood** is assigned quality = 2 (do not use). Note that **PBest** and **PGood** may be identical. In this case the temperature profile for altitudes above and including that pressure level is assigned quality = 0 whereas the temperature profile for altitudes below that pressure level is assigned quality = 2.
- **nBestStd** 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 $i = \mathbf{nBestStd}$, 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).
- **nGoodStd** 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 $i = \mathbf{nGoodStd}$., $\mathbf{nBestStd}-1$ 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).

The methodology of determining **PBest** and **PGood** is discussed later in this document.

Over ocean, **PGood** is often equal to **PBest** and the quality of the temperature profile levels is either 0 or 2. Over non-frozen ocean, there is sufficient spatial and temporal coverage of cases with **PBest** equal to the surface pressure, **PSurfStd**, to produce well-sampled climate data sets using only temperature profiles for which **PBest** = **PSurfStd**.

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Over land, if one considers only temperature profile data down to **PBest**, significant spatial and temporal sampling problems exist for pressures greater than 300 mb. For this reason, over land, if **PBest** \geq 300 mb, we set **PGood** equal to **PSurfStd** so that the quality of the temperature retrieval at pressures between **PBest** and **PSurfStd** is set to 1.

In all cases, the quality for temperature profile levels at $p > \mathbf{PGood}$ is assigned quality = 2 (do not use).

We also provide legacy temperature profile quality indicators that are backward compatible and consistent with V4 definitions:

- **Qual_Temp_Profile_Top** Quality indicator for **TAirStd** above height of pressure defined by **press_mid_top_bndry**
- **Qual_Temp_Profile_Mid** Quality indicator for **TAirStd** at heights between and including these pressure boundaries
- **Qual_Temp_Profile_Bot** Quality indicator for **TAirStd** below height of pressure defined by **press_bot_mid_bndry**

In V4, **press_mid_top_bndry** was always set to 200 mb, and **press_bot_mid_bndry** was set to the pressure corresponding to 3 km above the surface. In V5, the boundaries are case dependent and are set so as to be consistent with the intended use of **PBest** and **PGood**, with the additional constraint that **Qual_Temp_Profile_Mid** will always apply at 300 mb.

Users are encouraged to use **PBest** and **PGood** rather than these legacy quality indicators.

Quality Indicators for Other Retrieved Parameters

The quality indicators in the L2 output and their corresponding parameters:

- **Qual_Surf** Surface temperature and emissivity
- **Qual_H2O** Water products (see note below)
- **Qual_O3** Ozone
- **Qual_CO** Carbon monoxide
- **Qual_CH4** Methane
- **Qual_CO2** No product in V5
- **Qual_Cloud_OLR** Cloud fraction, cloud height, OLR
- **Qual_clrOlr** Clear-sky OLR
- **Qual_CC_Rad** Cloud cleared radiances

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- **Qual_Precip_Est** IR precipitation estimate (research product)
- **Qual_Clim_Ind** Coarse climate indicators (research product)

Special Note for Users of Moisture Profile Products

The **Qual_H2O** indicator applies to the total water burden.

For users of the moisture profile:

Qual_H2O = 0 the entire moisture profile is of highest quality (**PBest = PSurfStd**).

Qual_H2O = 1 the moisture is assigned a quality factor of 0 for layers whose pressure is less than **PBest**, and a quality factor of 1 for layers whose pressure is greater than **PBest**.

Combined IR/MW Retrieval Error Estimation

The following 16 quantities (also contained within the Level 2 Standard Product) are primarily indicative of values of different internal convergence tests. All differences are absolute values. They are used via regression to estimate errors in the surface temperature, air temperature profile at 100 levels, and the total water burden:

1.	totcloudh2o	total liquid water
2.	CC1_Resid	fit parameter for first cloud clearing
3.	CCfinal_Resid	fit parameter for final cloud clearing
4.	CCfinal_Noise_Amp	amplification factor for SECOND cloud clearing
5.	AMSU_Chans_Resid	observed minus calculated for AMSU channel 5 in final state
6.	Tdiff_IR_MW_ret	difference in lowest 2 km between last AMSU and IR retrievals
7.	Surf_Resid_Ratio	ratio of residual in surface retrieval to expected noise
8.	Temp_Resid_Ratio	ratio of residual in temperature retrieval to expected noise
9.	CC1_noise_eff_amp_factor	effective noise amplification factor in first cloud clearing
10.	CC_noise_eff_amp_factor	effective noise amplification factor in last cloud clearing
11.	TSurfdiff_IR_4CC2	difference between final Tsurf and that used in second cloud clearing.
12.	Initial_CC_Score	fit residual for reconstruction.
13.	TotCld_4_CCfinal	cloud fraction from IR retrieval
14.	Water_Resid_Ratio	ratio of residual in water retrieval to expected noise
15.	Tdiff_IR_4CC1	difference in lowest 2 km between startup state and IR retrievals
16.	TSurfdiff_IR_4CC1	difference between final Tsurf and that used in first cloud clearing

The error estimate, δx_i , for geophysical parameter i for a particular profile is:

$$\delta x_i = \sum_{k=1}^{16} M_{i,k} y_k$$

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where y_k is the value of parameter k for a given case. There are separate matrices M for non-frozen ocean cases and land/ice cases. The coefficients of these matrices were trained on the full day of retrievals for 9/29/04 using the ECMWF 3-hour forecast for that day as “truth”.

Temperature error estimates at 6 levels (151 mb, 260 mb, 497 mb, 707 mb, 853 mb, 986 mb) are then used to predict errors via a second regression for water at 100 levels and for the cloud cleared radiances. Since these six predictors are themselves based only on the original 16 predictors and can be thought of as pseudo-principal components, these estimates are also based indirectly only on the original 16 predictors.

Error estimates for other quantities in the output files are either internal noise covariance estimates, varying by case, or ensemble error estimates, constant over all cases with a particular processing path. All error estimates are constrained not to fall beneath minimum values.

How Combined IR/MW Quality Control is Set Upon Completion of Final Retrieval

Preliminary Determinations

There are some preliminary determinations made which are then used to set the quality indicators. The first decision is between the final retrieval and the fallback state. The fallback state is chosen whenever:

- (a) the final retrieval fails to complete,
- (b) the total cloud fraction (#13 above) is greater than 90%,
- (c) the regression PC score (#11 above) exceeds 10, or
- (d) the effective amplification from the first cloud clearing (#9 above) exceeds 300.

If the fallback case is selected, **Qual_Cloud_OLR** is set to 1, all other quality indicators are set to 2, and none of the following logic applies.

If the final state is selected, **Qual_Cloud_OLR** is set to 0 and the other quality indicators are set via the following prescriptions.

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A temperature error profile is defined by one of three cases:

- (a) Non-frozen ocean with liquid water covering >99% of FOV (**MWSurfClass** = 2) with surface error estimate > 1K
- (b) Non-frozen ocean with surface error estimate < 1K
- (c) Land, coast, or ice

The profiles are defined by a value at 70 mb, **PsurfStd/2** (representative of the pressure at the middle of the atmosphere), and **PsurfStd**, interpolated linearly in pressure. The values for the three cases are:

Case	TAirStdErr @70mb	TAirStdErr @PSurfStd/2	TAirStdErr @PsurfStd
a	1.75 K	1.25 K	1.75 K
b	2.25 K	1.75 K	2.75 K
c	2.25 K	2.0 K	2.0 K

A pressure level **PBest** is then set by comparing the temperature quality profiles with the level-by-level error estimates (at 100 levels) beginning downward from 70 mb. If the error estimate exceeds the quality profile for three consecutive levels, **PBest** is set to the level above the first of those three levels.

Over ocean, **PGood** is always set equal to **PBest**. Over land or ice, if **PBest** is greater than 300 mb, **PGood** is set equal to **PBest**; if **PBest** is less than 300 mb, **PGood** is set equal **PSurfStd**.

An internal “**constituent good**” indicator is set to “true” if the total water vapor error estimate is less than 35% of the total retrieved water vapor.

The degrees of freedom for the CO (**CO_dof**) and CH4 (**CH4_dof**) retrievals are used directly as outlined below.

The residual for the methane retrieval (**CH4_Resid_Ratio**, analogous to predictor #14 above) is used in CH4 quality control.

Limit checks are made for values far out of range of the RTA range of validity.

The individual quality indicators are then set as follows:

Qual_Temp_Profile_Top

If the final state is selected, the top of the profile is marked quality = 0, with the boundary between top and middle set at the higher elevation of **PBest** or 300 mb.

Qual_Temp_Profile_Mid

This is the quality at 300 mb, determined from **PBest** and **PGood**. The boundaries above and below are set as needed to represent **PBest** and **PGood**.

Qual_Temp_Profile_Bot

This is the quality of the surface air temperature, up to the lower elevation of **PBest** or 300 mb. The three temperature indicators will only have two distinct values as only **PBest** divides the atmosphere into two regions, but we have maintained backward compatibility to the three indicators in V4.

Qual_Surf

The surface quality **Qual_Surf** is set by testing the surface temperature error estimate, **TSurfStdErr** against a threshold.

Over Ocean:

Qual_Surf = 0 if **TSurfStdErr** < 0.8 K

Qual_Surf = 1

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)

Qual_Surf = 2 if **TSurfStdErr** fails test

Over Land:

Qual_Surf = 1 if **PBest** ≥ 300 mb

Qual_Surf = 2 if **PBest** < 300 mb

Qual_H2O

If the “**constituent good**” indicator is “true” and **PSurfStd** > **PBest** > 300 mb, then **Qual_H2O** = 1.

If the “**constituent good**” indicator is true and **PBest** = **PSurfStd**, then **Qual_H2O** = 0.

See the “Special Note for Users of the Moisture Profile” appearing on page 8 of this document.

Qual_O3

If the “**constituent good**” indicator is “true”, **Qual_O3** = 0.

Qual_CO

If the “**constituent good**” indicator is “true” and **CO_dof** > 0.4, then this indicator is set to 1.

If the “**constituent good**” indicator is “true” and **CO_dof** > 0.5, then this indicator is set to 0.

Qual_CH4

If **CH4_Resid_Ratio** < 1.5 and:

If the “**constituent good**” indicator is “true” and **CH4_dof** > 0.4, this indicator is set to 1.

If the “**constituent good**” indicator is “true” and **CH4_dof** > 0.5, this indicator is set to 0.

otherwise the indicator has value 2.

Qual_CO2

This indicator is always set to 2 in V5. All values in the CO₂ profile are set to the assumed first guess, i.e., they are not a retrieved quantity in V5. The first-guess value of the CO₂ concentration (parts per million by volume) is calculated for each footprint via the following algorithm:

$$CO2_ppmv(t) = 371.92429 + 1.840618 \times \Delta t$$

where the time between the current FOV and 0^{hr} UT on Jan 1, 2002:

$$\Delta t = (t_{FOV} - t_{0UT_01Jan02})$$

is expressed in fractions of a year. This linear fit to the time variation of CO₂ observed at Mauna Loa is applied globally to avoid non-linear effects in the RTA calculation that could arise from very large differences between assumed and true CO₂ concentration, while at the same time not introducing geospatial or seasonal variations that might leak into the planned future CO₂ retrieval.

Qual_Cloud_OLR

As stated at the beginning of this section:

If we accept a final retrieval, **Qual_Cloud_OLR** = 0.

If we output the fallback state this indicator is set to 1.

In the event that the cloud retrieval is not completed this indicator is set to 2.

Qual_clrolr

If the “constituent good” indicator is “true”, **Qual_clrolr** = 0; otherwise this indicator is set to 2.

Qual_CC_Rad

If **PBest** >= 300 mb, this indicator is set to 0. Otherwise this indicator is set to 2.

Qual_Precip_Est

If we accept a final retrieval, this indicator is set to 0.

If we output the fallback state this indicator is set to 1.

If the cloud retrieval is not completed this indicator is set to 2.

Qual_Clim_Ind

If the “**constituent good**” indicator is “true”, this indicator is set to 0; otherwise it is set to 2.