Improved Determination of Surface and Atmospheric Temperatures Using Only Shortwave AIRS Channels: The AIRS Version 6 Retrieval Algorithm

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AIRS was launched on EOS Aqua on May 4, 2002 together with ASMU-A and HSB to form a next generation polar orbiting infrared and microwave atmosphere sounding system (Pagano et al 2003). The theoretical approach used to analyze AIRS/AMSU/HSB data in the presence of clouds in the AIRS Science Team Version 3 at-launch algorithm, and that used in the Version 4 post-launch algorithm, have been published previously. Significant theoretical and practical improvements have been made in the analysis of AIRS/AMSU data since the Version 4 algorithm. Most of these have already been incorporated in the AIRS Science Team Version 5 algorithm (Susskind et al 2010), now being used operationally at the Goddard DISC. The AIRS Version 5 retrieval algorithm contains three significant improvements over Version 4. Improved physics in Version 5 allowed for use of AIRS clear column radiances $\hat{R}_i$ in the entire 4.3 μm CO_2 absorption band in the retrieval of temperature profiles *T(p)* during both day and night. Tropospheric sounding 15 μm CO_2 observations were used primarily in the generation of clear column radiances $\hat{R}_i$ for all channels. This new approach allowed for the generation of accurate Quality Controlled values of $\hat{R}_i$ and *T(p)* under more stressing cloud conditions. Secondly, Version 5 contained a new methodology to provide accurate case-by-case error estimates for retrieved geophysical parameters and for channel-by-channel clear column radiances. Thresholds of these error estimates are used in a new approach for Quality Control. Finally, Version 5 contained for the first time an approach to provide AIRS soundings in partially cloudy conditions that does not require use of any microwave data. This new AIRS Only sounding methodology was developed as a backup to AIRS Version 5 should the AMSU-A instrument fail. Susskind et al 2010 shows that Version 5 AIRS Only sounding are only slightly degraded from the AIRS/AMSU soundings, even at large fractional cloud cover.

Significant further progress has been made by the AIRS Science Team since the delivery of the AIRS Version 5 retrieval algorithm to form the AIRS Science Team Version 6 AIRS/AMSU retrieval algorithm. The Version 6 retrieval algorithm is for the most part very similar to Version 5 with one major exception. As in Version 5, the generation of cloud cleared radiances $\hat{R}_i$ for all channels is performed using observed radiances R_i for longwave 15 μm and 11 μm channels. Tropospheric temperature profiles were retrieved in Version 5

using only the AIRS shortwave 4.2 μm CO_2 channels, but surface skin temperature T_{skin} was retrieved simultaneously with surface spectral emissivity and bi-directional reflectance using observations both in the longwave 8-12 μm window region and in the shortwave 4.0 μm – 3.76 μm window region. In Version 6, only window observations in the shortwave window region, 4.0 μm – 3.76 μm are used to determine surface skin temperatures as well as shortwave surface spectral emissivities and surface bi-directional reflectance. The current use of only shortwave AIRS channels in the retrieval of both atmospheric and surface parameters has resulted in significant improvement in the ability to obtain both accurate temperature profiles and surface skin temperatures under more stressing partial cloud cover conditions.

Figure 1 shows a typical AIRS brightness temperature spectrum and includes the channels used in Version 6 for cloud clearing, and in each of the different steps of the AIRS physical retrieval algorithm. Channels used only for cloud clearing are shown in yellow and those used to determine *T(p)* as shown in red. CO_2 channels in the 15μm region sensitive only to stratospheric temperature are used only in the determination of temperature profile and those sensitive to tropospheric temperature are used only for cloud clearing purposes. The channels shown in blue are used both for the determination of T_{skin} and *T(p)*.

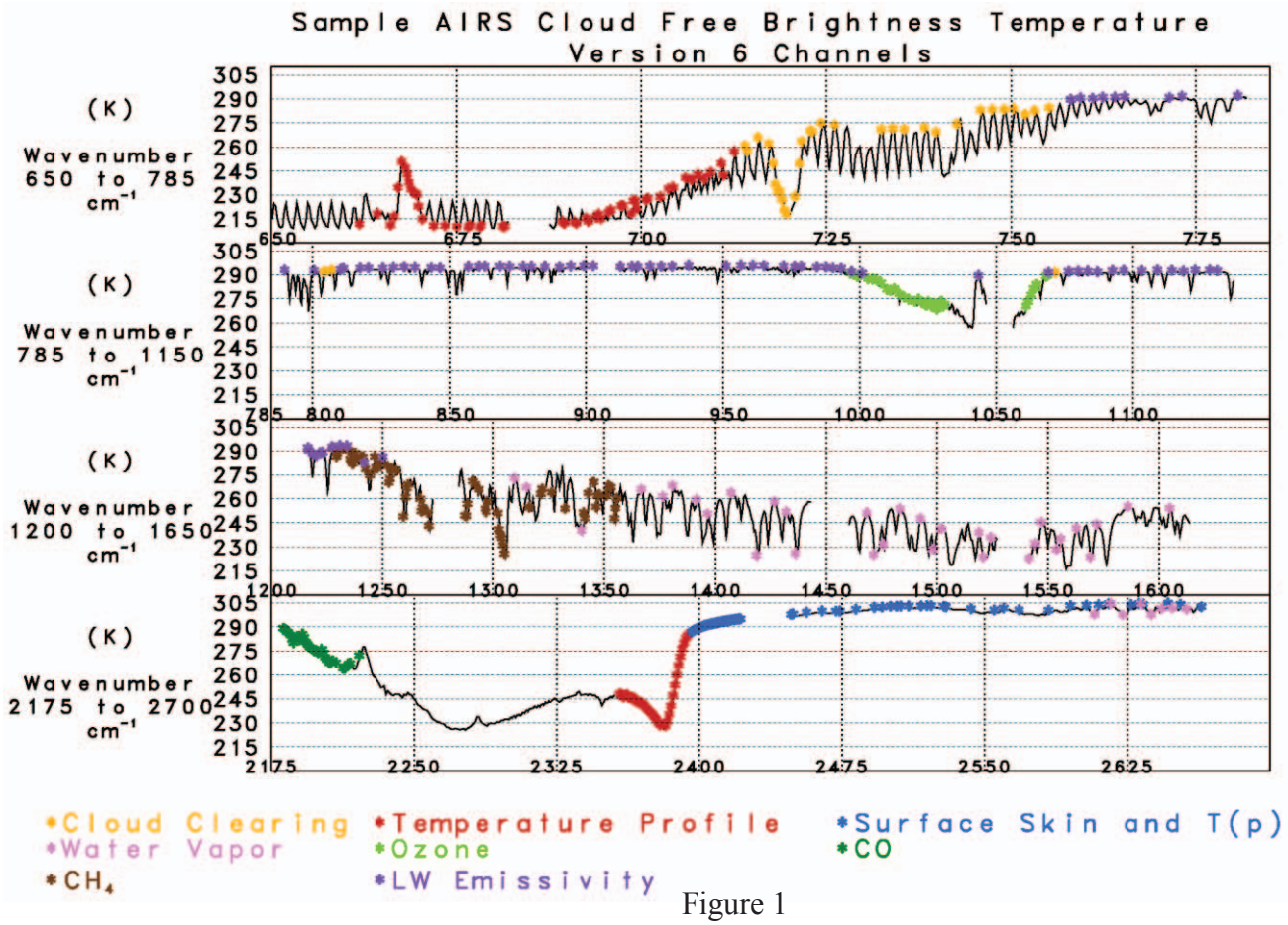

Figure 1

As with earlier versions, constituent profile retrievals are performed in separate steps, each having their own set of channels and functions. Figure 1 shows in different colors the Version 6 channels used in each of these retrieval steps. The *q(p)* retrieval (pink stars) uses 33 channels in the spectral ranges 1377 cm^{-1} to 1605 cm^{-1} and 2608 cm^{-1} to 2656 cm^{-1}; the $O_3(p)$ retrieval (green stars) uses 41 channels between 997 cm^{-1} and 1069 cm^{-1}; the *CO(p)* retrieval (green stars) uses 36 channels between 2181 cm^{-1} and 2221 cm^{-1}; and the $CH_4(p)$ retrieval (brown stars) uses 71 channels between 1230 cm^{-1} and 1356 cm^{-1}.

Version 6 Quality Controlled atmospheric temperature profiles are considerably more accurate than those of version 4, especially under cloudier conditions. The major difference between these two sets of results is due to the fact that most of the tropospheric temperature profile information in Version 4 came from the use of $\hat{R}_i$ for 15 μm CO_2 channels in the retrieval process, while Version 6 does not use $\hat{R}_i$ for any tropospheric sounding 15 μm CO_2 channels. There were also other differences between Version 4 and Version 6 as well, such as the Quality Control methodology. AIRS Version 5 used both 11μm and 3.7μm window channels in the determination of T_{skin} over ocean and land areas. The Version 6 algorithm uses only 3.7 μm channels for this purpose. In a manner analogous to the methodology in the determination of temperature profiles by using only shortwave CO_2 channels for tropospheric temperature sounding, this major change in methodology results in considerable improvement in the ability to obtain accurate SST's under more difficult cloud conditions by using $\hat{R}_i$ for only shortwave window regions to solve for T_{skin} as compared to combined use of $\hat{R}_i$ in both the longwave and shortwave window regions. Results obtained during the day are at least as good, if not better, than those obtained at night.

This improved sounding methodology is made possible as a result of a few factors, both theoretical and instrumental. First of all, use of improved radiative transfer physics allows for the accurate computation of the effects of non-LTE on the observed radiances in the 4.2 μm CO_2 band during the day. Secondly, the cloud clearing methodology used to analyze AIRS data removes the effects of solar radiation reflected by clouds from the clear column radiances $\hat{R}_i$ used to generate the solution. Effects of solar radiation reflected by the surface on the shortwave radiances are accounted for directly as part of the surface parameter retrieval process. Also, improved error estimates and Quality Control methodology allows for the screening of cases in which aspects of the retrieval methodology may have performed poorly.

Finally, and most significantly, use of these theoretical improvements is made practical because the noise in the AIRS shortwave channels is extremely low. This approach is not practical using IASI data because the IASI noise is too high in the shortwave portion of the spectrum. The findings of this paper are significant with

regard to design considerations of future high spectral resolution IR sounders, especially for geostationary (GEO) orbit. It is optimal on such sounders to have spectral coverage beyond 2400 cm^{-1} with very low noise, to produce accurate soundings under most cloud conditions. It is not essential for advanced IR GEO sounder to be accompanied by a GEO microwave sounder to achieve these results.

REFERENCES

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