

Retrieving Infrared Land Surface Emissivity With AIRS Simulation Data

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Abstract

This report reviews briefly the characteristics of high spectral resolution satellite infrared remote sensing. The paper also describes the use of EOS-Aqua AIRS measurements to characterize the surface properties important for IR thermal emission. Infrared rapid transmittance model is used for the sensitivity study of surface parameters and the atmospheric parameters from lower troposphere. Six standard model atmospheres are utilized to generate the simulated AIRS radiances. An experiment is carried out to retrieve the land surface emissivity with the AIRS simulation data. The MLEV (Minimum Local Emissivity Variance) retrieval method is implemented for this simulation study.

Introduction

The Atmospheric InfraRed Sounder (AIRS) is the first of a new generation of high spectral resolution atmospheric sounders. AIRS is the infrared instrument onboard the NASA Earth Observing System Aqua satellite launched on May 4, 2002. It is a grating spectrometer designed to measure the upwelling radiances from the Earth and its atmosphere with 2378 spectral channels between 650-2670 cm⁻¹ with a spectral resolving power on the order of 1200. Details on the AIRS instrument and performance are given in Aumann et al. (2003). AIRS is a multi-purpose instruments used for measuring global atmospheric temperature, water vapor, trace gas concentration, surface temperature, surface emissivity, aerosols, as well as cloud parameters and cloud properties. AIRS observation should lead to significant advances on the weather prediction and the better understanding of the climate (Goldberg, 2003).

In this paper, MLEV technique is utilized for its particular advantage of the continuous sampling of

long-wave infrared radiances available with high spectral resolution instruments, simultaneously determining land surface temperature and land surface emissivity spectrum. The optimal land surface temperature and land surface emissivity spectrum solution derived from MLEV is that which yields the smallest local spectral variation of the derived emissivity spectrum from synthetic AIRS data.

Sensitivity Study for Land Surface Emissivity

SARTA (Stand-Alone Radiative Transfer Algorithm) is a fast forward model developed by AIRS team (Strow et al. 2003). SARTA could generate very quickly a simulated AIRS radiances and transmittance spectrum for any plausible atmosphere profile. It has 100 layers with pressures from 1100hPa at the bottom to 0.005hPa at the top of atmosphere. We used the SARTA fast model to calculate simulated radiances for the ECMWF profiles within an AIRS granule on Sept. 6, 2002. The difference between the SARTA simulation and the real AIRS observation provides an estimate of the accuracy of the parameterizations and approximations introduced in SARTA model. Figure 1 shows the mean brightness temperatures and standard deviation errors of SARTA model for all clear fields of view within AIRS granule 182. For long-wave AIRS band, the mean biases are about -1K to 1K , while the standard deviations are around 1K for most channels within this band.

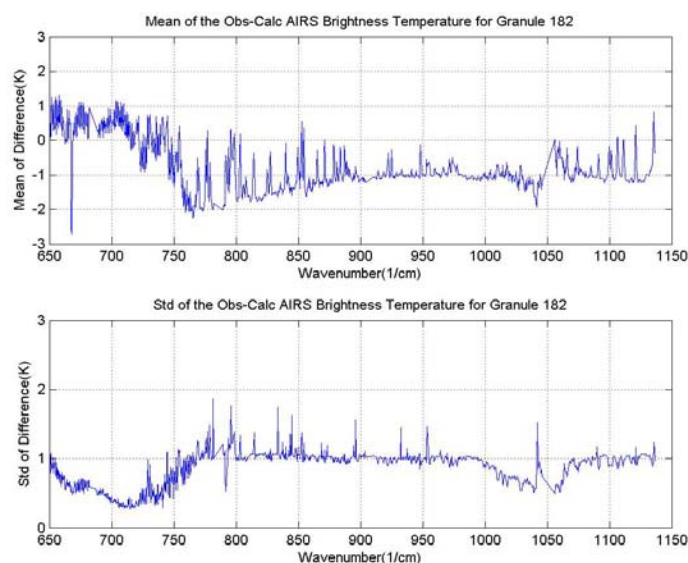


Fig.1: The mean and standard deviation between the calculated and observed AIRS brightness temperature for all clear fields of view within granule 182 of Sept.6, 2002

The emissivity spectral distributions are determined as a function of assumed surface emissivity increment for six standard model atmospheres (1976 U.S. standard, tropic, mid-latitude winter, mid-latitude summer, subarctic summer, subarctic winter) to demonstrate the information content of the simulation radiances. The results are shown in Figure 2 through 4. Figure 2 displays the change of synthetic radiances

(in brightness temperature) with the assumed surface emissivity increment of 0.01 for two different standard atmospheres. The upper panel is for 1976 U.S. standard, and the lower one is for tropic atmosphere. For AIRS long-wave band, the brightness temperature is increased to 0.7K for most channels. Only some channels have been affected in the water vapor band. For shortwave band, the brightness temperature is increased much less, about 0.2K. Figure 3 is similar to figure 2 except for mid-latitude winter atmosphere and mid-latitude summer atmosphere. Figure 4 is the similar result for subarctic summer and subarctic winter atmospheres.

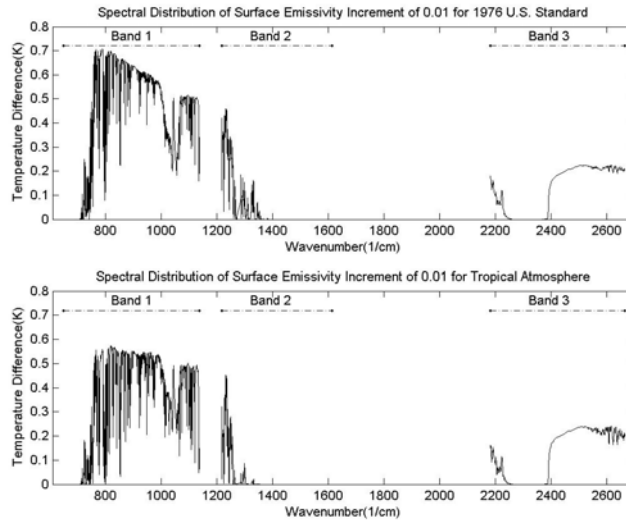


Fig.2: Spectral distribution of surface emissivity increment of 0.01 for 1976 U.S. and tropic atmospheres

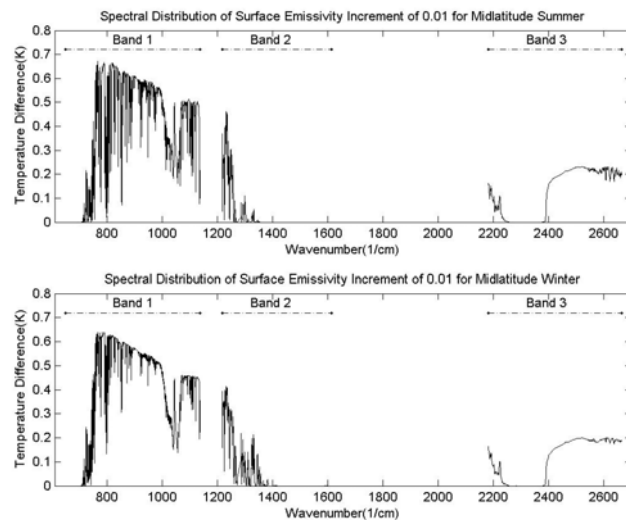


Fig.3: Spectral distribution of surface emissivity increment of 0.01 for midlatitude summer and midlatitude winter atmospheres

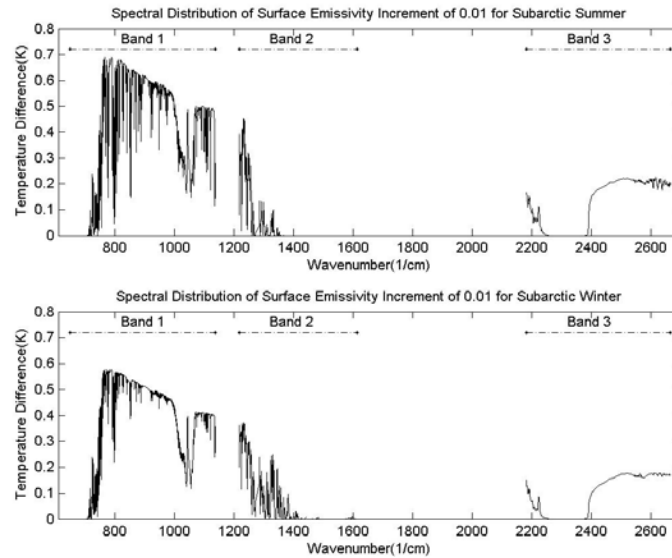


Fig.4: Spectral distribution of surface emissivity increment of 0.01 for subarctic summer and subarctic winter atmospheres

Sensitivity Study for Atmospheric and Surface Parameters

Similar sensitivity study was carried out for atmospheric and surface parameter variation as in the previous session, SARTA fast forward model was used as again to generate synthetic radiances for 1976 U.S. standard atmosphere. The results are shown in Figure 5 through 6. Figure 5 displays the change of synthetic radiances (in brightness temperature) with the assumed temperature increment of 1K. The upper panel is for surface temperature increase, and the lower one is for low troposphere temperature increase. For AIRS long-wave band, the brightness temperature is increased to 1K for most channels, only part of water vapor band has been affected. For shortwave band, the brightness temperature is increased by 1K with the exception for transparent window channels. Figure 6 displays the change of synthetic brightness temperature with variation of low troposphere humidity and ozone profile. The upper panel is for humidity decrease of 15%. Note that the temperature difference exists nearly everywhere in the entire infrared region. It is caused by the attenuation due to water vapor absorption, which has an impact on AIRS radiances in the whole region. The lower panel is for ozone decrease of 10%. In contrast with water vapor absorption, ozone only has a significant impact on AIRS radiances in localized spectral regions.

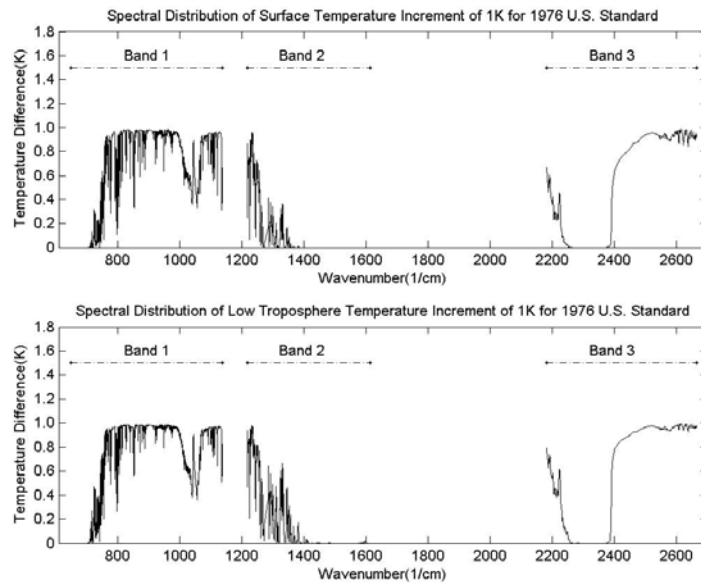


Fig.5: Spectral distribution of surface temperature and low troposphere temperature increment of 1K for 1976 U.S. standard atmosphere.

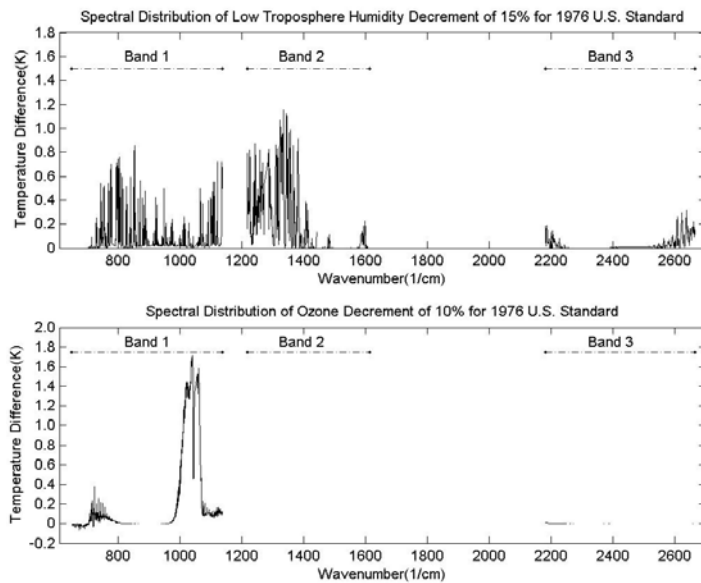


Fig.6: Spectral distribution of low troposphere humidity decrease of 15% and ozone decrease of 10% for 1976 U.S. standard atmosphere

Retrieving LSE With Simulation AIRS Data

To achieve the objectives of obtaining accurate atmospheric profiles over land, the land surface

temperature (LST) has to be known to a target accuracy better than 0.5K and land surface emissivity (LSE) to an accuracy better than 0.01. High spectral resolution measurements have the potential to allow the separation of LST and LSE (Knuteson et al. 2003). Figure 7 is a diagram for MLEV technique.

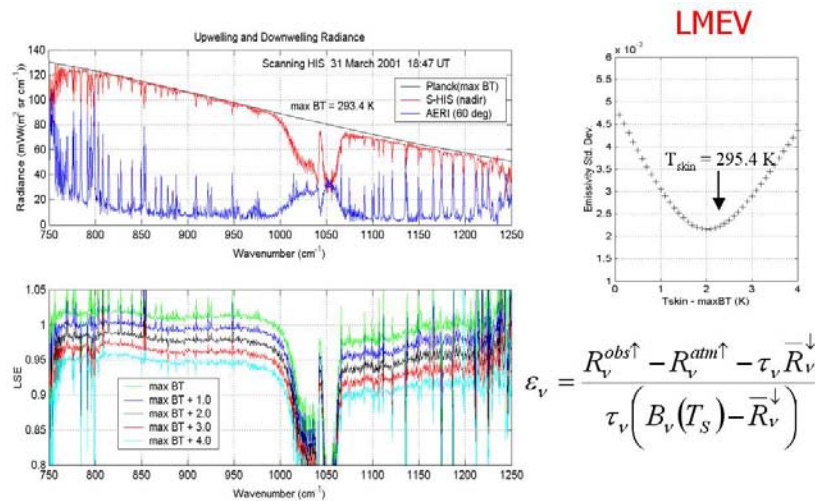


Fig7: The S_HIS and AERI observations used in the MLEV technique are shown in the upper panel. The lower panel shows a range of surface skin temperature values. The best fit is the one which minimizes the spectral line variations of the derived emissivity. (Courtesy of Robert Knuteson).

The MLEV land surface temperature and land surface emissivity retrieval principle is demonstrated by comparing the land surface emissivity and its local variance determined as a function of assumed land surface temperature. The land surface emissivity spectrum and land surface temperature are selected for that land surface temperature for which the derived land surface emissivity exhibits minimal local spectral variation and a structure that is uncorrelated with the local variations in radiances produced by absorption lines. MLEV algorithm is named after the principle that the optimal land surface emissivity spectrum should have the feature of “minimum local emissivity variance” among the retrieved emissivity spectra associated with different land surface temperatures.

Figure 8 shows the determined surface emissivity with variation of surface temperature estimate. Of the three estimates shown in this figure. The optimum surface temperature is the one calculated emissivity has a maximum smoothness. Error occurs with an over- or under-estimation of the surface skin temperature.

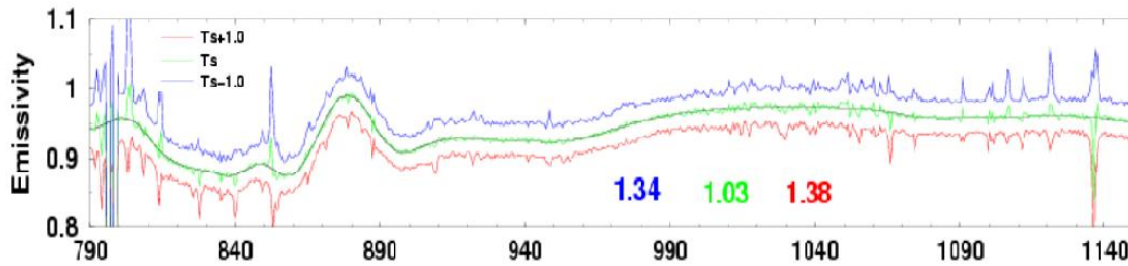


Fig8: The emissivity spectra derived with the wrong/correct surface temperature. Error occurs with an over- or under-estimation of the surface skin temperature

Discussions and Future Plans

SARTA model is used for the sensitivity study of surface parameters and the atmospheric parameters from lower troposphere. Six standard model atmospheres are utilized to generate the simulated AIRS radiances. MLEV is a relatively simple technique that takes advantage of the continuous sampling of long-wave infrared radiance measurements, simultaneously determining land surface temperature and land surface emissivity spectrum. The optimal land surface temperature and land surface emissivity spectrum solution derived from MLEV is that which yields the smallest local spectral variation of the derived emissivity spectrum. A near future study will involve the implementation of MLEV technique for the real hyperspectral AIRS measurements, in conjunction with its validation.

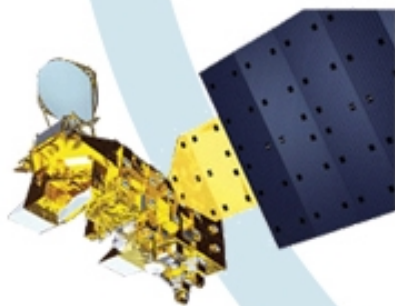
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