A high spectral resolution global land surface infrared emissivity database
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Background & Overview

An accurate infrared land surface emissivity product is critical for deriving accurate land surface temperatures, needed in studies of surface energy and water balance. An emissivity product is also useful for mapping geologic and land-cover features. Current sensors provide only limited information useful for deriving surface emissivity and researchers are required to use emissivity surrogates such as land-cover type or vegetation index in making rough estimates of emissivity. Inaccuracies in the emissivity assignment can have a significant effect on atmospheric temperature and moisture retrievals. To accurately retrieve atmospheric parameters, a global database of land surface emissivity with the spectral resolution is required.

A global infrared land surface emissivity database with high spectral and high spatial resolution is introduced. The database is derived from a combination of high-spectral-resolution laboratory measurements of selected materials, and the UW/CIMSS Baseline Fit (BF) Global Infrared Land Surface Emissivity Database (Seemann et al., 2007) by using principal component analysis (PCA) regression. The goal of the work is to create a spectrum of emissivity from 3.6 to 14.5 μm (for a given month) for data/infrared/imagery collected at 0.05-degree spatial resolution of 416 wavenumbers. To create a high-spectral-resolution emissivity database the PCs (eigenvectors) of laboratory spectra are regressed against the UW/CIMSS BF emissivity data. The characteristic of the input data, the methodology, how many PCs to use and some tests on laboratory measurements, the Seedar clear sky training profile database and AIRS clear sky single FOV retrievals are presented.

Methodology

A statistical regression method was used to combine the first Principal Components (PCs) of 123 selected laboratory spectra from the MODIS13H and ASTER emissivity libraries (wavenumber resolution between 2.4nm at 416 wavenumbers) and the 10 hinge points of the monthly UW/CIMSS BF emissivity data (see equations below). High spectral resolution emissivity values were determined at each MYD11 latitude and longitude point over land. The accuracy of the new UW/CIMSS HSR emissivity database is dependent upon the input BF emissivity data and the MODIS MYD11 measurements. The BF approach uses selected laboratory measurements of emissivity to derive a conceptual model, or baseline spectra, and then incorporates MODIS MYD11 measurements (at six wavelengths: 3.8, 3.9, 4.0, 8.6, 11, and 12 μm) to adjust the emissivity at 20-bm wavelengths (3.3, 4.6, 5.6, 6.7, 6.8, 7.3, 9.3, 10.8, 12.2, and 14.3 μm) to adjust the emissivity at 20-bm wavelengths (3.3, 4.6, 5.6, 6.7, 6.8, 7.3, 9.3, 10.8, 12.2, and 14.3 μm).

How many PCs to use?

In the PCA technique the first PCs with highest eigenvalues represent real variances in the data while the last, least significant PCs mask other represent random noise. In this study we determine the PC number to be 20 due to the number of spectral points of the input BF emissivity. To determine the number of PCs to use, the following functions/ tests were performed: the percentage cumulative variance function of the 123 lab data, the magnitude of the determination of the inverse matrix in the equation of the PCA coefficients (see above), the reconstruction error of the lab data and the value of the newly calculated emissivity spectra longer than 3 in the Seedar training dataset. These tests indicate that in this study the optimal number of PCs is 6. A larger number of PCs makes the results unstable.

Using the first 6 PCs, the new HSR emissivity spectra of the land profiles of the Seedar training data is shown below.

Example using SeeBor training data

Conclusions and Future Work

A methodology to create a high spectral resolution emissivity database from the moderate spectral resolution UW/CIMSS BF emissivity database was described. A software tool to extract the high spectral resolution emissivity database from the UW/CIMSS BF emissivity database will be available in early 2008. A data version is available for testing.

The comparison of the UW/CIMSS BF and UW/CIMSS HSR emissivities indicated that the largest differences occur around at 13, 10.2-9.7 μm for the IGBP barren/desert land classification. Other comparisons indicated that the largest differences are shown for a constant emissivity of 1.0 (black) and those derived by linear interpolation between MYD11 wavelengths (green), both compared with the same 123 laboratory spectra. This analysis is intended to illustrate how well these schemes can reproduce the full spectrum of emissivity.

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Sensitivity of calculated IR BT to a change in emissivity

The prototype of the CRIS instrument was used to calculate BT for MODIS clear sky land profiles from the Seedar training dataset to evaluate the sensitivity of emissivity on all 2378 AIRS channels. Average differences of calculated BT using different emissivity spectra (BF BF and HSR emissivities) are plotted separately for some selected IGBP ecosystem types. The largest differences between BF and HSR emissivities and BT calculated with these two emissivities occur around at 13, 10.2-9.7 μm. The largest differences in emissivity spectra (emis=1, BF emis and HSR emis) are plotted separately for some selected IGBP ecosystem types. The largest differences between BF and HSR emissivities and BT calculated with these two emissivities occur around at 13, 10.2-9.7 μm.

Comparison with the input BF emissivity data

Test on laboratory data

Mean absolute emissivity difference (left) and standard deviation of emissivity difference (right) between 223 laboratory spectra and final derived by the BF method (black) and PCA regression method (red), using the first 6 PCs. The line emissivity values at the 6 MYD11 wavelength and at the 12 emission points were input into the BF and HSR schemes respectively to get the corresponding 223 laboratory spectra.

Differences are also shown for a constant emissivity of 1.0 (black) and those derived by linear interpolation between MYD11 wavelengths (green), both compared with the same 123 laboratory spectra. This analysis is intended to illustrate how well these schemes can reproduce the full spectrum of emissivity.