Retrieval of Land Surface Infrared Charateristics from Simulated HES Radiances

Robert O. Knuteson, Eva Borbas, Szu Chia Moeller, Henry E. Revercomb, Suzanne Seeman and David C. Tobin
Cooperative Institute for Satellite Meteorological Satellite Studies, University of Wisconsin-Madison

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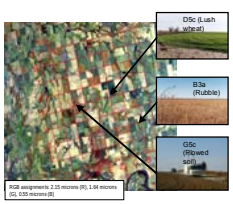
Introduction

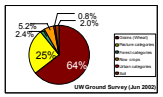
The Hyperspectral Environmental Suite (HES) on GOES-R and beyond will enable improved monitoring of the temporal evolution of land surface temperature and infrared surface emissivity. The HES is expected to provide hourly top of atmosphere radiance observations with a spatial resolution of better than 10 km and a spectral resolving power of greater than 1000. The University of Wisconsin is using existing observations from ground-based, aircraft, and satellite platforms to develop a simulation of the outgoing surface radiation of a land site in North Central Oklahoma. The Department of Energy Atmospheric Radiation Measurement Program Southern Great Plains (DOE ARM SGP) site is being used because of the extensive network of atmospheric profiling measurements routinely collected at that site. High spectral resolution infrared observations from the ground-based UW Atmospheric Emitted Radiance Interferometer (AERI) have been made of the time rate of change of surface emitted thermal radiance at this site but only for select land cover types. Similar aircraft observations have been made of the DOE ARM SGP site by the UW Scanning High-resolution Interferometer Sounder (S-HIS) at a spatial resolution of about 2 kilometers from a high altitude aircraft platform. Likewise, the EOS Aqua platform with the Atmospheric InfraRed Sounder (AIRS) instrument is being used to obtain high spectral resolution satellite observations at a spatial resolution of about 15 km. The EOS AIRS data provides the first nearly complete global observational dataset at high spectral resolution suitable for the development of land surface retrieval algorithms with the goal of improving the lower tropospheric sounding of temperature and particularly water vapor. Retrieval techniques are being compared using AIRS data over selected ground targets. MODIS global derived infrared emissivities have also been used to create a global gridded database for spectral regions important for HES sounder simulations. Simulations tied to these measurements are being used to develop algorithms for the generation of effective land surface emissivity and effective land surface temperature products derived from the geostationary observations anticipated in the GOES-R time frame. A 24 hour data simulation of a candidate HES sensor has been created at 8 km spatial resolution that combines realistic surface emissivities and WRF model surface temperatures and atmospheric state profiles with an infrared radiative transfer model to compute TOA simulated HES radiances. This simulated dataset is being used in the development and testing of the time dependent surface temperature and emissivity algorithm.

Ground Truth Site: DOE ARM Southern Great Plain Site

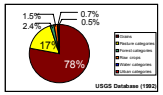
DOE ARM SGP Site



USGS Historical

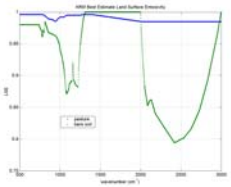


UW Survey



ER-2 Image of DOE ARM SGP central facility in north central Oklahoma. A UW ground based survey confirmed the vegetation cover.

Atmospheric Emitted Radiance Interferometer

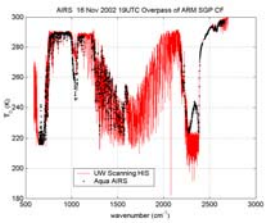


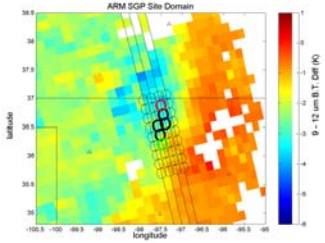
UW measurements of grass and bare soil at ARM SGP site.

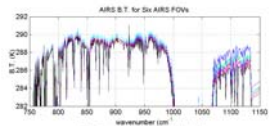
The UW-Madison land surface emissivity model for the ARM Southern Great Plains (SGP) site is a linear combination of measured pure scene type emissivities for pasture (dry grass canopy) and bare soil. The linear weighting can be interpreted as a fractional vegetation cover. The spectral emissivity is based upon UW ground-based AERI measurements. The fractional weighting is based on UW aircraft measurements for specific times with a coarse approximation to seasonal variation.

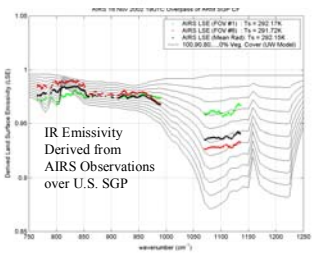
Atmospheric InfraRed Sounder (AIRS) Measurements

The launch of the EOS Aqua platform in 2002 with the NASA AIRS instrument opened a new era of high spectral resolution observations of infrared top of the atmosphere radiance in the thermal infrared. A detailed example is provided here of data from the AIRS sensor for an overpass on 16 November 2002 coincident with the UW Scanning HIS aircraft instrument. The data analysis shows that the AIRS satellite observations can be used to produce global surface emissivity maps that can be used to test GOES-R retrieval algorithms, with particular application to atmospheric sounding.





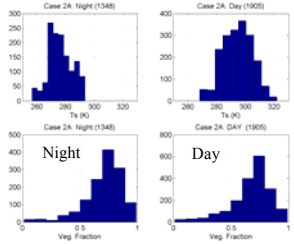




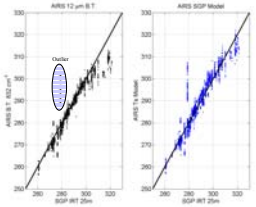
The AIRS hyperspectral satellite observations are a preview of the HES spectral content, but only at one time and for fairly large footprints (15 km). The ground-based ARM measurements are necessary for testing the validity of various satellite remote sensing techniques that take advantage of the high spectral resolution observations.

Validation:
ARM SGP CF site, Lamont, OK
- 25 meter tower downlooking IRT
- Aqua AIRS overapasses (2002-2004)
- The UW Spectral Variance technique is and a UW developed land surface model have been compared to ground-based truth measurements from the DOE ARM site.

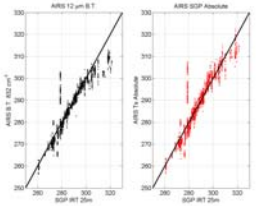
UW Surface Model Statistics



Note the similarity of Day & Night Vegetation Fraction from very different T_s distributions



UW Surface Model



UW Spectral Variance Method

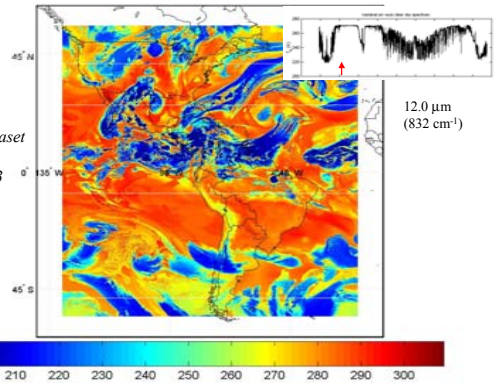
Satellite HES Simulations

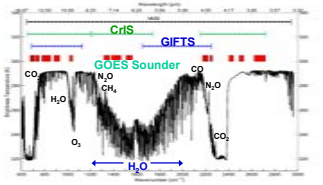
The UW CIMSS has begun a simulation project to combine a land cover map with emissivity assignment derived from satellite observations of AIRS and MODIS on the NASA Aqua platform with the NWP capabilities of the WRF model. The WRF model has been used to simulate the atmosphere during for a 24 hour period a nearly full disk coverage with 8 km spatial resolution and data output at 40 minute intervals. A UW developed global emissivity atlas with continuous spectral coverage in the infrared and the WRF model fields were input to the HES forward radiative transfer model to create top-of-atmosphere radiance fields. These TOA simulations are being used to test algorithms for the retrievals of atmospheric and surface properties with different methodologies and various assumptions on HES sensor channel availability.

HES WRF Simulation w/ Surface Emissivity Database

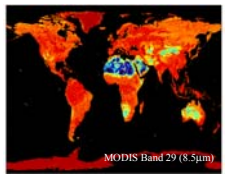
WRF HES "FullDisk" 24 Hour Dataset

24 June 2003 0600 UTC





HES Spectral Bands are yet to be determined so the simulations cover the entire infrared region.



MODIS emissivities provide realistic surface emissivity spatial variations to be augmented with AIRS data.

Retrieval Methods Under Study:

- Emissivity Atlas (a priori) with Land Surface Model
- Spectral variance (online/offline) Method
- ASTER Temperature and Emissivity Separation method
- Time evolution (e.g. MODIS day/night) method
- Statistical Regression against laboratory spectra
- Physical iterative simultaneous retrieval methodology

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