RADIANCE-BASED VALIDATION OF THE V5 MODIS LAND-SURFACE TEMPERATURE PRODUCT

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We present the results of the radiance-based validation approach for the MODIS (Moderate Resolution Imaging Spectroradiometer) Land-Surface Temperature (LST) product.. Surface emissivity spectra were retrieved by a sun-shadow method from surface-leaving radiance spectra measured with a thermal infrared spectroradiometer in the 3.5-14μm spectral region under sunshine and sun-shadow conditions. By using the measured surface emissivity spectrum and atmospheric profiles measured by radiosonde balloons, and the LST values at validation sites in the V5 MODIS LST products, radiative transfer simulations were made with the MODTRAN4 code to calculate the brightness temperatures (Tb) of MODIS TIR bands. The MODIS LST product is validated through comparisons between the calculated and MODIS measured Tb values in band 31. This approach is well compared to the conventional temperature-based approach using the validation data in Coll et al. (2005). Small differences of the Tb values (around ±0.3K in night cases and slightly larger in daytime cases) indicate that the accuracy of the MODIS LST product is better than 1K in vegetation sites in ideal clear-sky cases. However, the error in split-window retrieved LSTs is larger in bare soil sites due to large uncertainties in surface emissivities.

1. Introduction

In-situ data in early field campaigns (Wan et al., 2002 & 2004; Coll et al., 2005) and new field campaigns are used to validate the V5 MODIS Land-Surface Temperature (LST) products.

2. Methodology of the LST Validation

2.1, conventional temperature-based approach

Multiple TIR radiometers are used to measure the surface radiometric temperature. Effects of surface emissivity (ε) and reflected atmospheric radiation are corrected to obtain the in-situ measured LST using the emissivity value based on land-cover and/or sample measurements and atmospheric radiative transfer simulations. Comparisons between the in-situ LSTs and MODIS LSTs give the accuracy of MODIS LSTs.

This approach is limited by the spatial variation in LSTs, especially during daytime.

2.2, advanced radiance-based approach

Radiosonde balloons are launched to measure the atmospheric temperature and water vapor profiles around the MODIS overpass time. Based on the measured atmospheric profile, MODIS LST and the emissivity spectra measured in the field or estimated from land-cover and/or sample measurements, make a radiative transfer simulation with MODTRAN4.0 (Berk et al., 1999) to calculate the top-of-atmospheric (TOA) radiance L31 and brightness temperature (T_b) in band 31. Make another simulation with a different LST input, and then calculate the LST corresponding to the MODIS L31 by interpolation/extrapolation. Calculate the sky radiance with MODTRAN4.0 based on measured atmospheric profiles in Fig. 1. The excellent agreement (shown in Fig. 2) between the calculated sky radiance and the one measured with Bomem TIR spectroradiometer MR100 provides a solid evidence of the good quality of the spectroradiometer and the radiative transfer code. The main advantage of this approach: it does not need in-situ LST measurements so suitable for both daytime and nighttime.

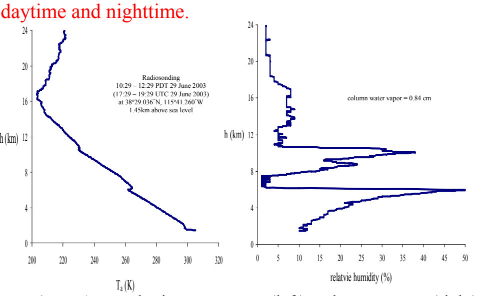

Fig. 1, Atmospheric temperature (left) and water vapor (right) profile smeasured by radiosonding over Railroad Valley, NV on 29 June 2003.

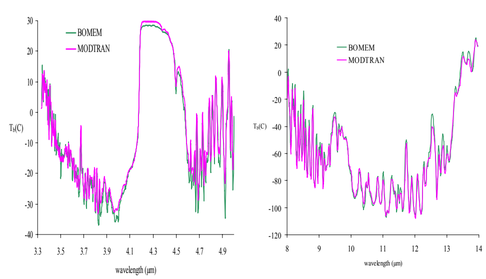

Fig. 2, T_b of downwelling radiance at nadir measured by Bomem TIR spectroradiomter at 10:30 PDT 6/29/03 in Railroad Valley and the T_b calculated by MODTRAN4.0 based on measured atmospheric profiles.

3. Radiance-based validation results

3.1, spectral emissivities measured with the sun-shadow method

We measured the surface-leaving day/night radiance under sunshine and shadow conditions with the spectroradiometer MR100 in a grassland in northern TX in April 2005 and a bare soil site at the west bank of Salton Sea, CA in June 2006. The sun-shadow method, a simplified version of the method (Wan and Li, 1997) was used to retrieve surface emissivities, as shown in Fig. 3.

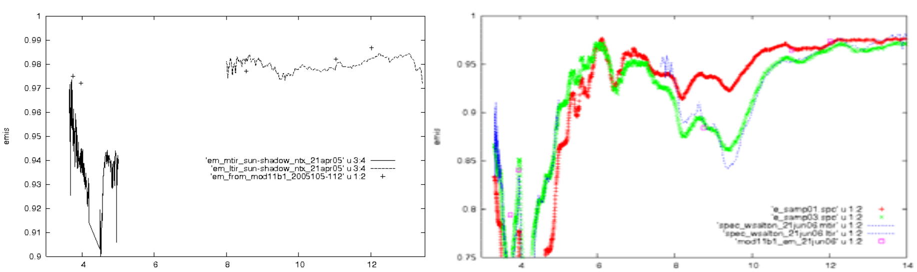

Fig. 3, ε spectra of a grassland in TX (left) and a bare soil site near Salton Sea, CA (right).

3.2, results of the radiance-based validation

The validation results of LSTs in V5 level-2 LST products in the TX grassland and the Spain rice sites (using grassland emissivity) are shown in **Tables I** and **II**.

Table I, Radiance-based validation of V5 Terra and Aqua MODIS LSTs at the grassland site, TX.

case no.	Granule ID (T/A)	date & time (m/d hh:mm)	viewing zenith angle (°)	cwv, Ts-air (cm, K)	MODIS LST (δT) (K)	ΔTb in b29 (K)	trans in b31	ΔTb in b31 (K)
1	A2005111.1755 (T)	4/21 10:55.26	22.0	0.35, 289.5	304.0 (0.4)	-0.2	0.95	-0.6
2	A2005112.0455 (T)	4/21 21:58.50	5.84	0.84, 282.2	278.3 (0.2)	+0.1	0.92	-0.2
3	A2005111.1930 (A)	4/21 12:30.42	44.9	0.58, 293.2	306.5 (0.1)	-0.6	0.92	-0.6
4	A2005112.0910 (A)	4/22 02:10.44	40.5	0.84, 280.2	278.3 (0.1)	+0.2	0.90	-0.3

Table II, Temperature-based (in-situ LST) and radiance-based (TOA L31 inverted LST) validations for the V5 Terra MODIS LST product at the rice field in Valencia, Spain (Coll et al., 2005). The atmospheric temperature and water vapor profiles used in the radiance-based validation were measured by radio sounding in Murcia, Spain (38.0°N, 1.17°W), about 160km south of Valencia. The mean and standard deviation of the differences between the in-situ LST and TOA L31 inverted LST values in six ideal clear-sky Terra (T) cases (in black) are 0.03K and 0.37K. The last 3 cases are for V5 Aqua MODIS LSTs.

case no.	Granule ID (T/A)	date & time (m/d hh:mm)	viewing zenith angle (°)	radiosonde cwv, Ts-air (in MOD07) (cm, K)	MODIS LST (δT) (K)	in-situ LST (K)	trans in b31	TOA L31 inverted LST (K)	profile-based Tb31-Tb32 (K)	MODIS Tb31-Tb32 (K)
1	2002191.1030 (T)	7/10 10:32	43.7	1.78, 307.8 (2.28,298.6)	300.7 (0.1)	302.0	0.75	299.6**	0.06	0.89
2	2002207.1030 (T)	7/26 10:32	43.7	2.35, 307.4 (3.47,296.9)	299.7 (0.1)	301.2	0.67	297.9**	0.26	1.43
3	2003189.1010 (T)	7/08 10:11	60.3	1.55, 306.8 (2.5, 299.9)	300.8 (0.1)	301.9	0.68	297.7*	-0.28	1.40
4	2003192.1040 (T)	7/11 10:42	27.7	1.98, 309.5 (2.16,302.4)	302.7 (0.3)	302.1	0.79	302.7	0.23	0.44
5	2003221.1010 (T)	8/09 10:11	60.5	2.75, 307.8 (2.39,299.3)	301.8 (0.7)	302.9	0.52	303.2*	1.31	1.38
6	2003224.1040 (T)	8/12 10:42	28.1	1.40, 306.8 (1.46,297.5)	304.3 (0.1)	304.4	0.82	304.1	0.05	0.49
7	2003238.1050 (T)	8/26 10:54	6.7	2.36, 308.2 (3.0, 297.4)	303.1 (0.2)	305.1	0.76	300.4**	0.22	1.55
8	2004190.1020 (T)	7/08 10:24	50.3	1.15, 302.8 (1.56,294.4)	298.6 (0.5)	298.5	0.79	298.9	0.14	0.52
9	2004209.1050 (T)	7/27 10:54	6.0	2.09, 307.1 (1.84,296.9)	301.5 (0.2)	301.1	0.77	301.2	0.17	0.56
10	2004216.1100 (T)	8/03 11:00	6.0	2.18, 308.0 (2.34,298.5)	303.1 (0.2)	303.2	0.76	302.8	0.34	0.78
11	2004225.1050 (T)	8/12 10:54	5.7	2.22, 306.9 (1.94,298.5)	301.9 (0.1)	301.9	0.76	301.7	0.26	0.58
12	2004190.1335 (A)	7/08 13:40	49.0	1.15,302.8 (1.99,299.6)	300.5 (1.2)		0.80	301.3	0.28	0.51
13	2004209.1230 (A)	7/27 12:33	51.1	2.09,307.1 (1.77,297.7)	301.7 (0.2)		0.67	301.7	0.38	0.79
14	2004225.1230 (A)	8/12 12:33	51.2	2.22,306.9 (2.62,302.6)	303.3 (0.3)		0.65	303.0	0.56	1.18

* Viewing angle > 60°; ** under influence of cloud contamination or heavy aerosols.

3.3, error analysis

As shown in Fig. 4, the error in LSTs is within ±0.5K over Salton Sea. But it ranges from -0.4 to -2.3K over the bare soil site on its west bank due to the large uncertainty in surface ε_{31} and ε_{32}, shown in Fig.3. Simulations indicate: (a) a variation of -0.01 in ε_{31}-ε_{32} changes LST by 0.8-1.5K; (b) a change of 0.01 in ε_{31} results in a Tb31 change of about 0.5K; (c) a change of -20% in cwv results in Tb31 changes up to 0.5-1K in the cwv range of 1-2cm.

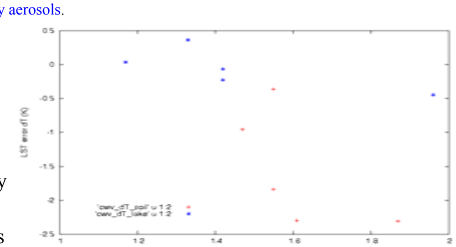

Fig. 4, Errors in LSTs retrieved by the split-window method and cwv in Salton Sea and nearby bare soil site.

4. Conclusion

The V5 MODIS LST products were validated, most within 1K in vegetation and lake sites. The LST errors are larger in bare soil sites due to large uncertainties in surface ε. The error in LSTs retrieved from the day/night method is smaller by about 0.5K.

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