Revealing Issues for Improving VIIRS Land Surface Temperature Retrieval

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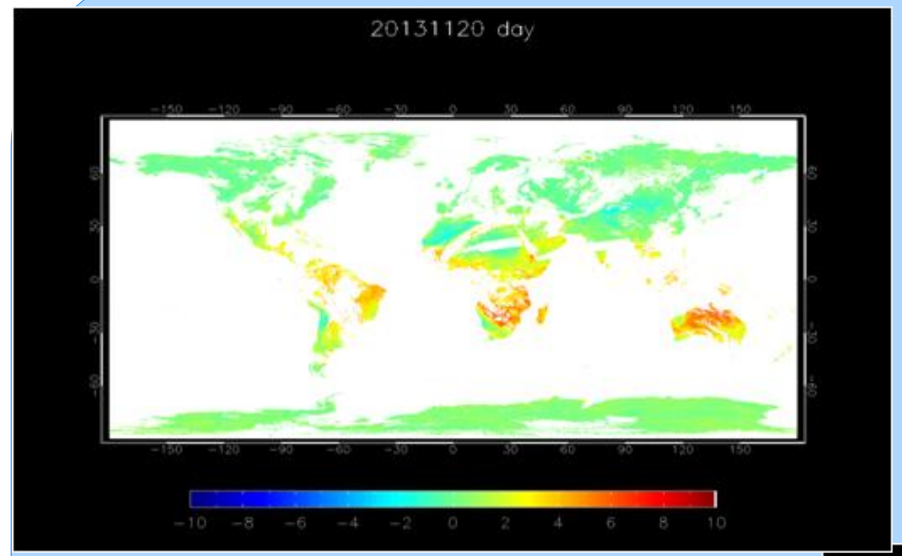
Introduction

The Visible Infrared Imager Radiometer Suite (VIIRS) on the Joint Polar Satellite System (JPSS) is one of the NOAA primary polar-orbiting satellite sensors. It can provide a series of Environmental Data Records (EDRs) including Land Surface Temperature (LST) product. The current VIIRS LST is generated from a surface-type dependent split window algorithm, which performs well for most surface types. There are still several issues which may causing uncertainties. Further improvements are necessary.

The satellites cross comparison between VIIRS and MODIS indicates that they agree with each other well under dry atmospheric condition, but there is some significant difference over wet regions mostly for daytime cases. In such regions, brightness temperature (BT) difference between split window channels is very large. We have performed some tests in different seasons over Australia to find the main factors related to high BT difference. We investigated the impacts of water vapor and emissivity on the LST retrieval. The results indicate that both water vapor and emissivity difference affect the BT difference, but water vapor is a dominant factor.

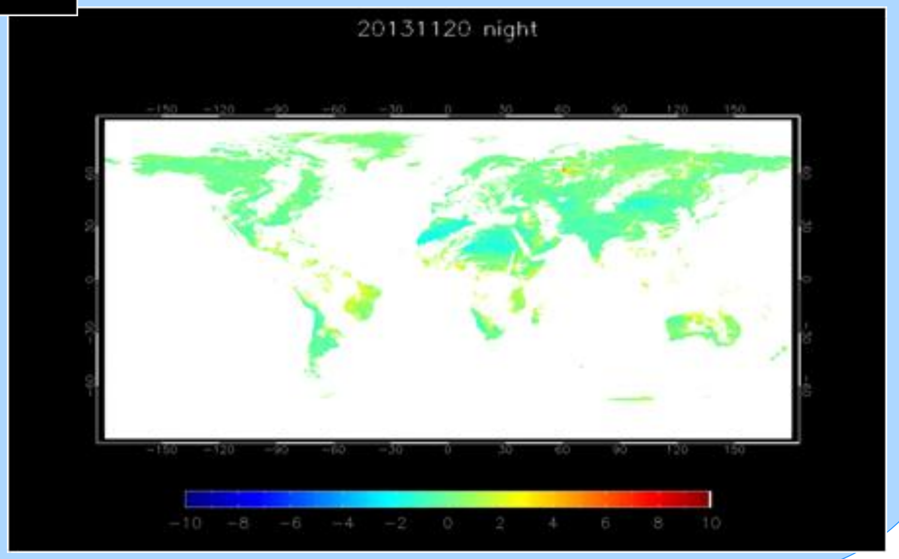
We have also tested an emissivity explicit algorithm in VIIRS LST retrieval, and its computed LSTs is more closer to Aqua LST than VIIRS beta version LSTs. The algorithms including water vapor terms in several different ways are tested. Some preliminary results are presented. All these studies provide a basis for our future algorithm improvements.

BT difference Issue



Brightness temperatures between the two split window channels on November 20, 2013.

Top Left: Day
Below right: Night



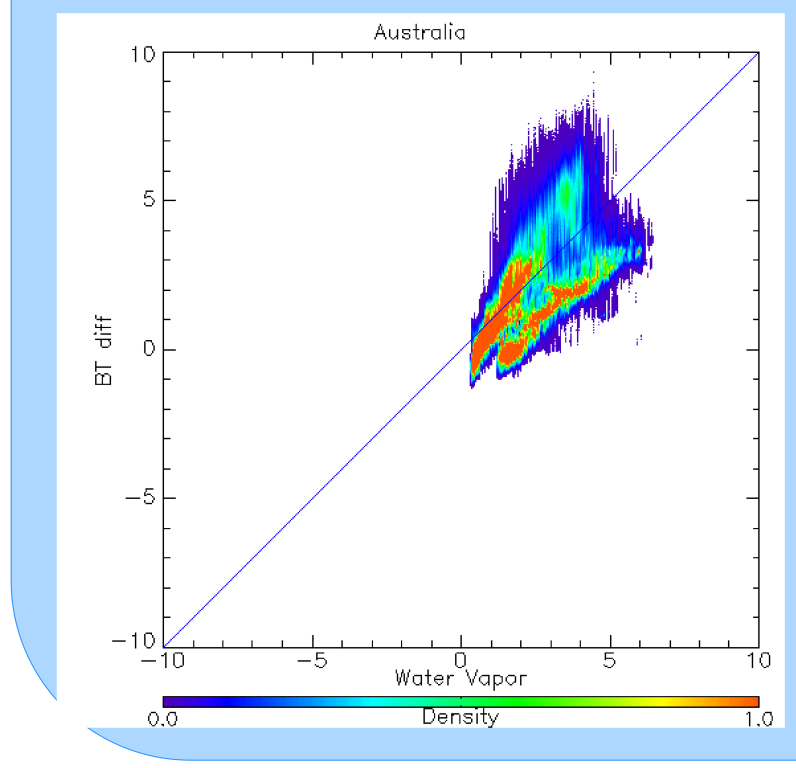
Significant difference found between VIIRS beta version LST and MODIS LST, mostly over wet regions; this is particularly true for daytime cases. In such regions, brightness temperatures difference between the two split window channels are very large. Investigation performed and found that additional correction should be made.

Further studies should be done in order to improve our LST product.

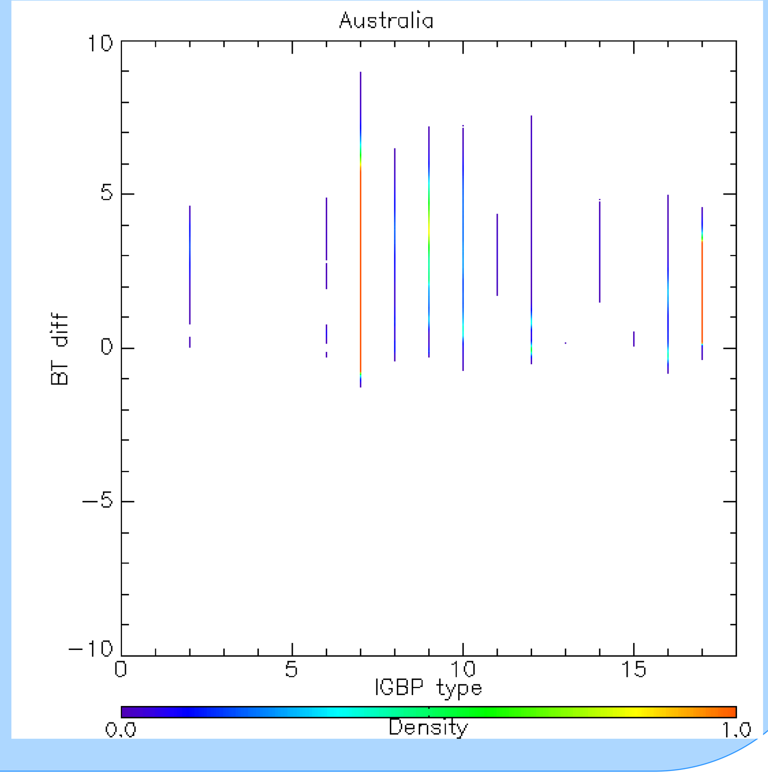
Water Vapor and Surface Type Impact on BT difference

Some granules in different seasons over Australia are chosen to analyze the factors which may affect BT difference. Later will check more regions and global.

Scatterplot of BT difference vs. water vapor shows that water vapor related to BT difference positively.

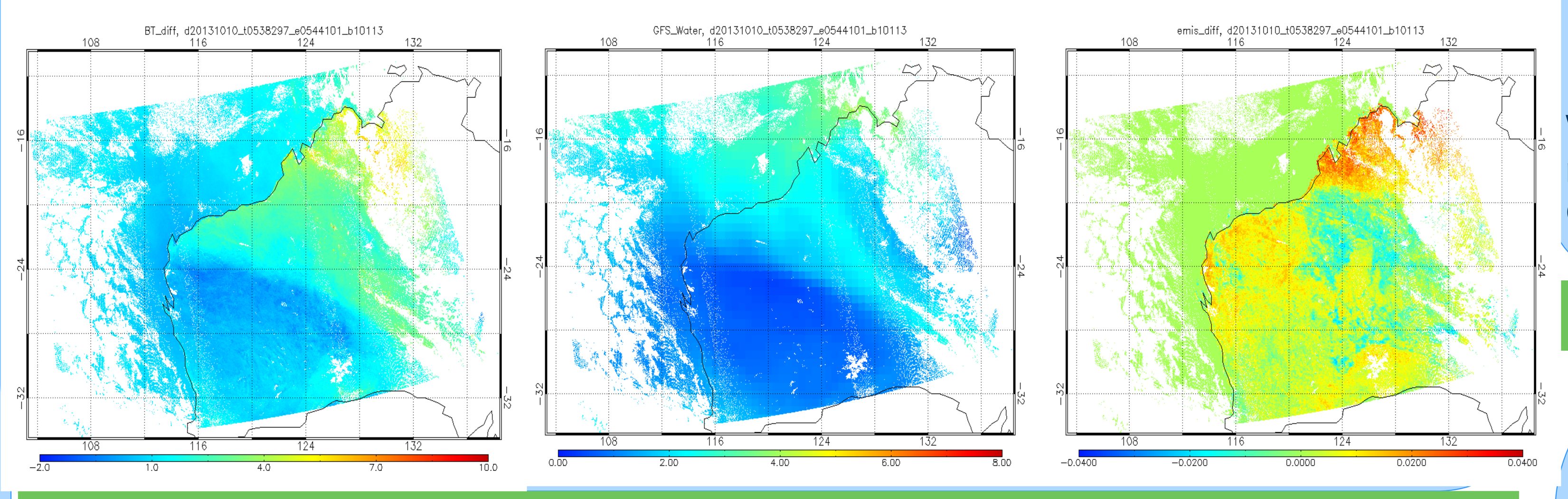


The figure of BT difference vs. Surface Type shows that large BT difference occurs mainly for IGBP 7, 9, and 10.



Water Vapor and Emissivity Impact on BT difference

The BT difference over land is usually larger than that over ocean, and it is affected by both water vapor and surface emissivity. The water vapor is a dominant factor, but the impact of emissivity is still under investigation. Left: BT difference, Middle: Water vapor, Right: emissivity difference.



Emissivity Impact on LST Algorithm Regression

In two emissivity datasets, IGBP types are represented by different emissivity pairs, which affects the simulation dataset regression process, and then affects the algorithm coefficients. The table shows the statistic comparison (Left: night; Right: day).

IGBP	Band-Averaged Emissivities in VIIRS testbed			MODIS 10-yr average Emissivity		
	Std	Min_dif	Max_dif	Std	Min_dif	Max_dif
1	0.483	-1.55	1.78	0.382	-1.42	1.49
2	0.335	-1.31	1.39	0.394	-1.47	1.64
3	0.447	-1.51	1.67	0.403	-1.41	1.48
4	0.461	-1.45	1.81	0.390	-1.45	1.59
5	0.418	-1.50	1.68	0.397	-1.40	1.52
6	0.695	-1.86	2.34	0.402	-1.41	1.60
7	0.485	-1.61	1.88	0.417	-1.45	1.59
8	0.409	-1.36	1.60	0.372	-1.40	1.52
9	0.375	-1.40	1.61	0.398	-1.43	1.66
10	0.502	-1.45	1.83	0.389	-1.43	1.60
11	0.462	-1.49	1.71	0.389	-1.44	1.53
12	0.367	-1.37	1.59	0.390	-1.44	1.58
13	0.462	-1.49	1.71	0.441	-1.45	1.76
14	0.656	-1.85	1.99	0.380	-1.40	1.58
15	0.398	-1.44	1.50	0.338	-1.25	1.38
16	1.332	-3.57	3.91	0.522	-1.68	1.98
17	0.327	-1.32	1.40	0.344	-1.27	1.41

IGBP	Band-Averaged Emissivities in VIIRS testbed			MODIS 10-yr average Emissivity		
	Std	Min_dif	Max_dif	Std	Min_dif	Max_dif
1	0.500	-1.25	1.24	0.488	-1.27	1.23
2	0.391	-1.02	1.03	0.410	-1.04	1.07
3	0.462	-1.22	1.19	0.495	-1.29	1.22
4	0.484	-1.28	1.24	0.488	-1.24	1.22
5	0.458	-1.25	1.19	0.493	-1.29	1.23
6	0.622	-1.52	1.49	0.497	-1.29	1.26
7	0.434	-1.11	1.17	0.503	-1.31	1.26
8	0.479	-1.21	1.25	0.474	-1.26	1.18
9	0.399	-1.01	1.04	0.487	-1.22	1.23
10	0.527	-1.31	1.31	0.488	-1.23	1.22
11	0.433	-1.10	1.14	0.485	-1.30	1.22
12	0.395	-1.06	1.03	0.470	-1.24	1.19
13	0.433	-1.10	1.14	0.492	-1.26	1.26
14	0.500	-1.21	1.31	0.455	-1.24	1.16
15	0.479	-1.15	1.14	0.464	-1.18	1.16
16	0.659	-1.60	1.59	0.450	-1.11	1.19
17	0.394	-1.00	1.03	0.464	-1.19	1.19

Algorithm Comparison

VIIRS granule	MODIS granule	Ts from ABI algorithm vs. MODIS		VIIRS Beta version Ts vs. MODIS	
		Mean bias	std	Mean bias	std
d20131102_t1704	2013306.1710	2.78	1.69	4.56	2.10
d20131121_t0745	2013325.0755	0.95	2.87	1.08	3.24
d20131121_t0746	2013325.0755	0.86	2.17	1.08	2.36
d20131126_t1532	2013330.1540	0.27	1.51	0.20	1.51
d20131210_t0624	2013344.0620	1.65	0.62	0.47	0.65
d20131201_t1118	2013335.1145	1.80	2.62	2.49	3.27
d20140209_t0608	2014040.0615	0.55	3.34	0.12	3.31
d20140209_t1114	2014040.1115	-0.72	1.71	1.48	1.68
d20140209_t1115	2014040.1115	0.27	1.34	-0.70	1.48

Simultaneous Nadir Overpass (SNO) comparison between AQUA and VIIRS computed LST from an emissivity explicit algorithm Eq. (1) , as well as VIIRS beta LST.

In general, Ts from emissivity explicit algorithm is more closer to Aqua LST than VIIRS Beta version Ts.

Emissivity Explicit Algorithm

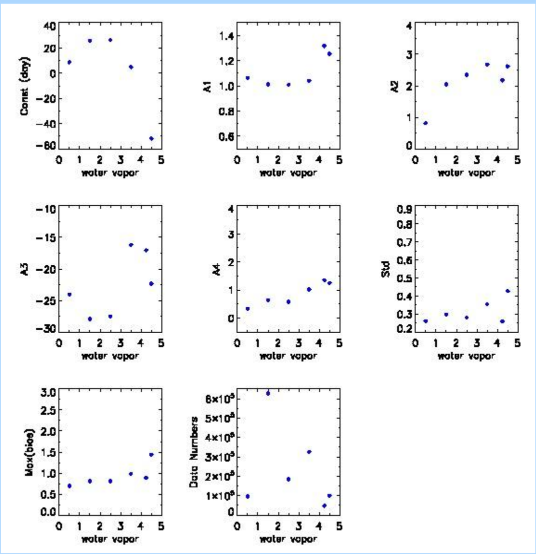
We have tested the emissivity explicit algorithm in VIIRS LST retrieval

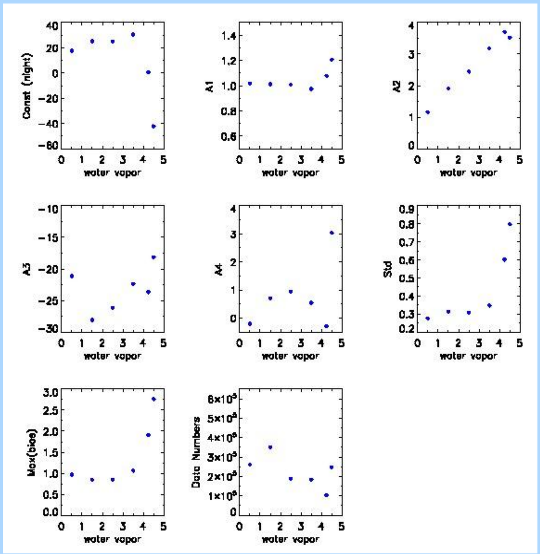
$$LST = C + A_1 T_{11} + A_2 (T_{11} - T_{12}) + A_3\,\varepsilon + A_4 (T_{11} - T_{12})(\sec\theta - 1) \qquad (1)$$

Where T_{11} and T_{12} are the brightness temperatures in 11.2 μm and 12.3μm bands, respectively. $\varepsilon=(\varepsilon_{11}+\varepsilon_{12})/2$, ε_{11} andε_{12} are the spectral emissivity in the split window bands. C, A_1, A_2, A_3, and A_4 are algorithm coefficients.

Water Vapor included Algorithm

To analyze how the water vapor affects the algorithm, I computed the algorithm coefficients for ABI algorithm for the following water vapor ranges: [0, 1], [1, 2], [2, 3], [3, 4], and [4, 4.5]. The following figures shows that each coefficient in Eq. (1) varies with water vapor obviously (Left: daytime, Right: nighttime)





The algorithm coefficients in Eq. (1) are adjusted by a quadratic function of water vapor term ($b_0 + b_1 W + b_2 W^2$) one by one. The mean bias can decrease 0.5K. Further improvement is still needed.

Summary and Future Work

We have evaluated the VIIRS LST using SNO comparison with Aqua LST. In general, VIIRS LST matches Aqua data well for dry condition. There are some significant bias over the wet regions for daytime cases. In such regions, the brightness temperature differences between split window channels are very large. Our analysis indicates that BT difference is affected by both water vapor and emissivity. Water vapor is a dominant factor, but the emissivity effect is still under investigation. Additional correction should be made to improve our LST product.

Impact of emissivity on the LST algorithm regression is also investigated.

We have tested an emissivity explicit algorithm, and also add water vapor terms in the algorithm. the mean bias of LST is decreased.

All these studies provide a basis for our future algorithm improvements.