WATER SURFACE TEMPERATURE RETRIEVAL FOR A SMALL LAKE USING ASTER THERMAL INFRARED DATA

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1. INTRODUCTION

Many water bodies like lakes and marshes are inhabited by many lives. For these lives, water temperature is an important environmental factor, giving some impacts to the activity of planktons and the solubility of oxygen. However, the water temperature is not fully or never monitored for most of small water bodies unlike some of major water bodies. Thus, we are developing a water temperature database for small water bodies in Japan using thermal infrared (TIR) data observed by the ASTER instrument onboard NASA's Terra satellite which was launched in December 1999 and is still in operation.

The ASTER project provides surface temperature and surface spectral emissivity products which are produced on-demand from an observed radiance product by atmospheric correction and temperature/emissivity separation, but these products will be degraded by processing errors like atmospheric correction errors under humidy conditions and by sensor problems like straylight effects on small targets. Thus, we have deployed water temperature loggers in Lake Senba, a small lake in Japan, to validate water temperature retrieval from small water bodies. In the present study, we demonstrate some early results from this validation activity.

2. LAKE SENBA VALIDATIOIN SITE

Lake Senba is a fresh water lake in Kairakuen Garden, Mito City, which is one of the top three gardens in Japan. The lake has an area of 0.33 km^2, a shoreline of 3.1 km, and a mean depth of 1.0 m. Fig. 1 shows the location of the lake on an ASTER near-infrared image, and a photo of Lake Senba is given by Fig. 2. The lake is inhabited by various lives like swan, and is visited by many citizens for relaxation, but gets water-bloom breeding in summer due to eutrophication.

For the validation study, we deployed Thermocron temperature loggers around the lake center in August 2009. The loggers have been measuring bulk water temperatures at 3 to 5 cm below the surface in a 10-min interval in 0.1 degree C increments. Fig. 3 shows a photo of the temperature logger with a float.

3. METHODOLOGY

For more accurate water temperature retrieval, more accurate radiometric calibration and atmospheric correction are necessary. For small water bodies, MTF, straylight, and mixel effects also need to be reduced. Since the ASTER standard processing does not include all latest algorithms, we applied alternative processing. First, recalibration [1][2] and straylight correction [3] were applied to observed radiance images, where some of MTF effects would be reduced through the straylight correction. Next, the modified observed images were atmospherically corrected using the water vapor scaling (WVS) method [4][5], and then a surface kinetic temperature image and surface spectral emissivity images were retrieved by the ASTER standard temperature/emissivity separation (TES) algorithm [6]. Since water has a flat and high emissivity spectrum, the spectral emissivity images can be used for quality assessment of the retrieval.

4. VALIDATION STUDY

By the end of January 2010, five daytime scenes and four nighttime scenes were acquired by ASTER under cloud-free conditions over Lake Senba (day: 2009/9/7, 10/9, 10/16, 11/26, and 2010/1/13; night: 2009/9/5, 11/8, 12/26, and 2010/1/27). Fig. 4 displays the in-situ water temperatures with daily max/min air-temperatures at Mito City and the nine ASTER overpasses.

To validate the methodology described above, we applied the standard atmospheric correction (STD) [7] and the WVS method to the nine ASTER scenes for the following cases: case 1) both recalibration (RC) and straylight correction (SC) are on, case 2) RC is off but SC is on, case 3) RC is on but SC is off, and case 4) both RC and SC are off. In each atmospheric correction, we used MODTRAN 4.2 combined with atmospheric profiles derived from NCEP's Global Data Assimilation System (GDAS) products. The results are given by Table 1. The RMS error shown in the table is the root mean square of the difference between the ASTER-based water temperature and the in-situ water temperature. A recalibration effect depends on the scene observation date. The results indicate that it is a little larger (0.3 to 0.4 K) in September 2009. A straylight effect depends on spatial contrast of surface temperature around the target—it will raise observed temperature if a target has a lower temperature than its surrounding area (typical daytime lake observations), and will lower it if not so (typical nighttime lake observations). In the results, the straylight effects for the water temperature retrieval are +0.2 to +0.9 K in daytime and –0.3 to –0.8 K in nighttime. The comparison results between STD and WVS indicate that WVS gives more accurate estimates than STD, and the expected accuracy of WVS is about 0.7 K while that of

STD is about 1.6 K. In these comparisons, we need to pay attention to the skin temperature effect, but comparing to bulk temperatures may practically match our purpose.

5. CONCLUSIONS

The water surface temperature database for small water bodies in Japan is under development. The lake Senba validation site was established for validation of water temperature retrieval for small water bodies. The nine validation results before the end of January 2010 indicated that the WVS algorithm with the recalibration and the straylight correction worked successfully, and its expected accuracy is about 0.7 K.

6. ACKNOWLEDGEMENT

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7. REFERENCES

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Fig. 1. Location of Lake Senba validation site.

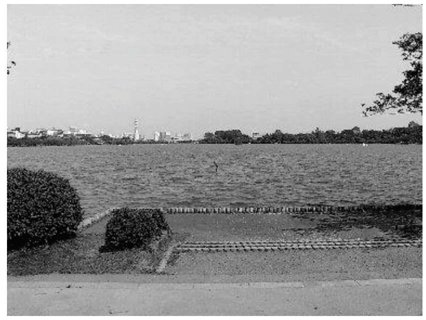

Fig. 2. Photo of Lake Senba.

Fig. 3. Photo of a water temperature logger with a float.

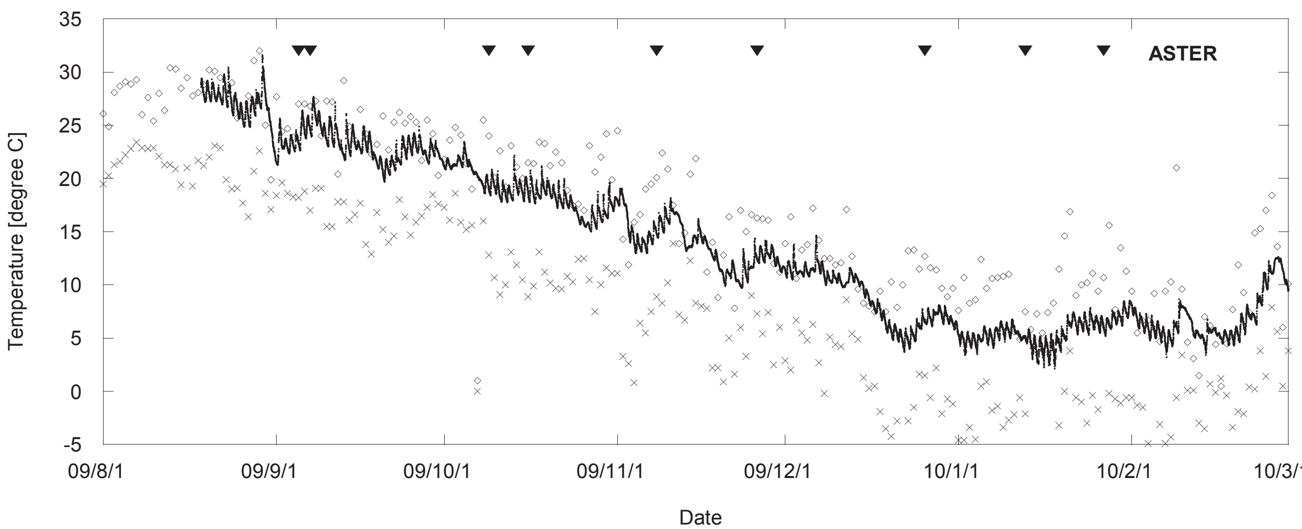

Fig. 4. Water temperatures obtained by the temperature loggers (solid line). Open diamond and cross plots show daily max/min air-temperatures at Mito city. Nine ASTER overpasses are also shown.

Table 1. Comparison of water surface temperatures (degree C) between in-situ buoy measurements and ASTER estimates for the standard atmospheric correction (STD) and the water vapor scaling (WVS) method for four cases (RC: recalibration, SC: straylight correction).

Date	In-situ	Case 1 RC: on, SC: on		Case 2 RC: off, SC: on		Case 3 RC: on, SC: off		Case 4 RC: off, SC: off	
		STD	WVS	STD	WVS	STD	WVS	STD	WVS
09/9/5 (Night)	25.1	26.5	25.0	26.2	24.6	26.1	24.5	25.9	23.9
09/9/7 (Day)	25.9	27.2	26.2	26.9	25.8	28.1	26.9	27.9	26.5
09/10/9 (Day)	19.7	21.8	21.2	21.8	21.2	22.6	21.9	22.6	21.9
09/10/16 (Day)	20.3	22.4	20.6	22.4	20.5	22.8	20.9	22.8	20.9
09/11/8 (Night)	16.0	17.1	15.9	17.1	15.9	16.8	15.5	16.8	15.4
09/11/26 (Day)	13.0	14.9	13.3	14.9	13.3	15.3	13.7	15.3	13.6
09/12/26 (Night)	7.0	6.4	6.9	6.4	6.8	6.1	6.5	6.1	6.4
10/1/13 (Day)	5.2	5.3	5.0	5.3	5.0	5.5	5.3	5.5	5.2
10/1/27 (Night)	6.4	3.8	5.0	3.8	4.5	3.4	4.2	3.4	4.2
RMS error	-	1.6	0.7	1.6	0.8	2.0	1.2	2.0	1.2