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Monitoring of Temperature Change about Cheonji for Bio Ecology Environmental Management

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Abstract

Currently, remote sensing technology is used in various ways in research on vegetation change detection or temperature variant detection in inaccessible areas or extensive areas. Especially, it is very useful for target area needing very continuous change detection. This study detected temperature variant using remote sensing technology in Cheonji lake in the highest mountain Mt. Baekdu, compared water temperature data in the tide station and temperature extracted from images to investigate the extracted temperature. As a result of temperature variant detection in Cheonji lake, from July 2000 to July 2010, it was presented that water temperature continuously increased, and in the future, hourly measurement and management of Cheonji lake water temperature will greatly contribute to the prediction and probability related research Mt. Baekdu volcanic eruption.

Keywords: *Baekdu mountain, Remote sensing, Landsat 7, Temperature change*

1. Introduction

Mt. Baekdu is located at longitude 128°60’ and latitude 42°70’ over the border of Korea and China, with height approximately 2,750m, the highest spiritual mountain. Chinese calls it Mt. Changbai [1]. It is a strato volcano or composite volcano with the upper part eroded by an enormous caldera with 5km in width and 850m in depth. This caldera was formed because of volcanic eruptions for 969 years (±20 years), filled with water to form Cheonji lake. Cheonji lake has a circumference of 12~14km; the average depth, 213m; and the maximum water depth of 384m, usually covered with ice and snow from mid-October to mid-June [2]. As recently geography academia included dormant volcano calling ‘one that used to erupt but recently is inactive’ in active volcano, Mt. Baekdu, too, can be viewed as an active volcano. This is because by the nature of volcano, it is almost impossible to predict when a volcano re-erupts even if it has stopped eruption. In fact, it is assumed that it is possible for earthquake that occurred on May 25, 2009 (Richter scale: 4.7) and violent earthquake that occurred on February 18, 2010 (Richter scale: 6.9) to have stimulated and activated the magma chamber under Mt. Baekdu [3]. Accordingly, ongoing, multifaceted, in-depth research on Mt. Baekdu with the risk of volcanic eruptions at the dimension of national disaster prevention is necessary.

Studies on Mt. Baekdu volcanic eruptions include: the study on volcanic rock mass, geological features and volcanic activity characteristics of the representative area, Mt. Baekdu of Manchuria area cenozoic era volcanic rocks distributed areas, as a part of research on Northeast Asia region cenozoic era volcanic activity and volcanic rock features [4]; the study

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that discovered the original data from historical records, analyzed Cheonji lake volcano eruption record and activity history in the historical period, and deleted errors of the quotes from the historical records, increased reliability of data and refinement [5]; and the study on the significance, current status and future prospects of 'the Study on the Feasibility of North-South Korean Research Collaboration on Northeast Asia's Environmental Changes using the Records of the Geological Features of Mt. Baekdu Cheonji lake' Unit Assignments carried out in the form of international joint research with China as well as North-South Korean cooperation project [6].

Mt. Baekdu's geographical location is at the border of North Korea and China, it is, in fact, not easy to access for South Korean scientists to study that except research collaboration with China. Thus, for research on areas and position where is not easy to access like Mt. Baekdu, remote sensing technology using images is frequently used [7-9].

Studies using remote sensing technology include surface deformation measurement of Mt. Baekdu area using DInSAR technology from 1992 to 1998 [10] possible surface deformation measurement of Mt. Baekdu area applying 2-pass DInSAR technology [11] and calculation of the surface temperature distribution of Cheonji lake volcano area using 9 infrared thermal images from 1999 to 2008 using satellite thermal infrared remote sensing technology [12].

This study extracted the water temperature of Cheonji lake at the top of Mt. Baekdu using time serial Landsat ETM+ satellite images, estimated the water temperature change amount, and through a cause analysis of this change amount, tries to provide useful basic data for the future water temperature change research on Cheonji lake.

2. Temperature Extraction and Investigation using Satellite Image Data

2.1. Temperature Extraction using Landsat Satellite Image

Among Landsat ETM+ images, Band61 and Band62 belong to the thermal infrared domain, the brightness of the images through these bands are disperse and reflected the strength of energy in this wavelength range and the surface of earth temperature through pre-set interaction formula. Thus, this study tries to extract the surface temperature of Cheonji lake based on NASA model reducing this radiometric quantity. the counting formula of absolute radiance using spectral radiance are like Formulae (1) and (2), and the spectral radiance value of Landsat ETM+ is like Table 2 [13, 14]. There are models reducing radiometric quantity RESTEC (Remote Sensing Technology Center of JAPAN) method and Quadratic method in addition to NASA model. NASA model mostly used among these methods was used.

$$L_\lambda = Grescale * QCAL + Brescale \tag{1}$$

Which is also expressed as :

$$L_\lambda = \left(\frac{LMAX_\lambda - LMIN_\lambda}{QCALMAX - QCALMIN}\right) * (QCAL - QCALMIN) + LMIN_\lambda \tag{2}$$

Where, L_λ= Spectral Radiance at the sensor's aperture in watts/(meter squared * ster * µm)
$Grescale$ = Rescaled gain (the data product "gain" contained in the Level 1 product header or ancillary data record) in watts/(meter squared * ster * µm)/DN

$Brescale$ = Rescaled bias (the data product "offset" contained in the Level 1 product header or ancillary data record) in watts/(meter squared * ster * µm)

$QCAL$ = the quantized calibrated pixel value in DN

$LMIN_{\lambda}$ = the spectral radiance that is scaled to QCALMIN in watts/(meter squared * ster * µm)

$LMAX_{\lambda}$ = the spectral radiance that is scaled to QCALMAX in watts/(meter squared * ster * µm)

$QCALMIN$ = the minimum quantized calibrated pixel value (corresponding to LMINλ) in DN

= 1 for LPGS products

= 1 for NLAPS products processed after 4/4/2004

= 0 for NLAPS products processed before 4/5/2004

$QCALMAX$ = the maximum quantized calibrated pixel value (corresponding to LMAXλ) in DN = 255

LMIN and LMAX indicate the spectral radiance for each band, values 0 or 1 to 255 are used. Table 2 shows the two sets of LMIN and LMAX for each band and gain.

Table 1. ETM+ Spectral Radiance Range

Unit : watts/(meter squared * ster * µm)

Band Number	Processed Before July 1, 2000				Processed After July 1, 2000			
	Low Gain		High Gain		Low Gain		High Gain	
	LMIN	LMAX	LMIN	LMAX	LMIN	LMAX	LMIN	LMAX
1	-6.2	297.5	-6.2	194.3	-6.2	293.7	-6.2	191.6
2	-6.0	303.4	-6.0	202.4	-6.4	300.9	-6.4	196.5
3	-4.5	235.5	-4.5	158.6	-5.0	234.4	-5.0	152.9
4	-4.5	235.0	-4.5	157.5	-5.1	241.1	-5.1	157.4
5	-1.0	47.70	-1.0	31.76	-1.0	47.57	-1.0	31.06
6	0.0	17.04	3.2	12.65	0.0	17.04	3.2	12.65
7	-0.35	16.60	-0.35	10.932	-0.35	16.54	-0.35	10.80
8	-5.0	244.00	-5.0	158.40	-4.7	243.1	-4.7	158.3

Band No. 6 of Landsat ETM+ image can be changed to more physically useful variables in spectral radiance suggested above. This is temperature in the satellite shown in the system of the Earth's atmosphere under the assumption of individual emissivity, and modification factor prepared in Table 3 is used. The transformation formula is like Formula (3).

$$T = \frac{K2}{\ln\left(\frac{K1}{L_{\lambda}} + 1\right)} \quad (3)$$

Where, T = Effective at-satellite temperature in Kelvin

$K1$= Calibration constant 1 from Table 3

$K2$ = Calibration constant 2 from Table 3

L_{λ} = Spectral radiance in watts/(meter squared * ster * µm)

Table 2. Thermal infrared band modification factor of Landsat 5 TM & Landsat 7 ETM+

	$K1$- Constant 1 watts/(meter squared * ster * µm)	$K2$- Constant 2 Kelvin
Landsat 5 TM	607.76	1260.56
Landsat 7 ETM+	666.09	1282.71

Since temperature obtained through Formula (3) is absolute temperature (K), to convert this to temperature (℃), 273.15 is subtracted like Formula (4).

$$T(℃) = T(K) - 273.15 \tag{4}$$

2.2. Extraction Temperature Investigation

To investigate the accuracy of temperature extracted from Landsat ETM+ images, this study used monitoring coastal oceanographic data provided from the National Oceanographic Research Institute (NORI). The NORI obtains and saves information such as tide level, water temperature and salinity through 46 tide stations, 6 marine observatories and 1 ocean research station, and services for general users to easily check it. This study used water temperature data of 3 tide stations (Incheon, Ansan and Pyeongtaek) located on the west coast to investigate the usefulness of temperature data obtained through satellite images.

Figure 1. Ansan Tide Station

Figure 2. Incheon Tide Station

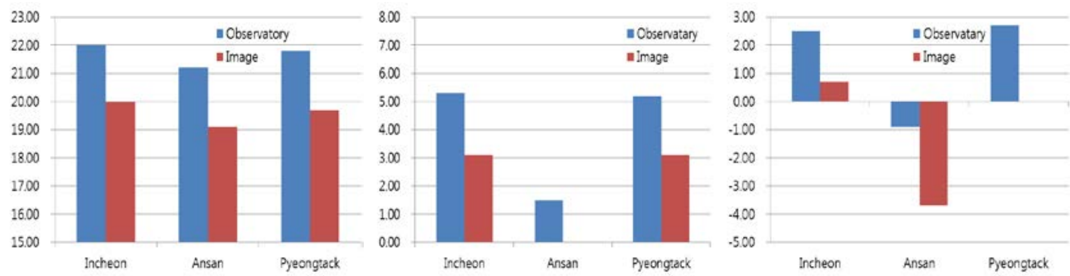
Figure 3. Pyeongtaek Tide Station

The reason why the three stations on the west coast were chosen is that they are located on the west coast with at a high latitude and large daily change amount among tide stations servicing water temperature.

For the images, thermal infrared band B62 was used among the Landsat ETM+ image same as those used for the temperature extraction of Mt. Baekdu Cheonji lake. By directly comparing the water temperature data in the same period of the date when the images were shot to the extracted temperature, the extracted temperature was investigated. Table 3 and Figure 4 show the comparison between the observatory data and the temperature extracted from the images. The temperatures were from minimum 1.80℃ to maximum 2.70℃, and showing an average of difference of 2.23℃, and the temperature extracted from the images was lower than those measured in the real observatory.

Table 3. Temperature Comparison between Observatory Data and Image Extraction

Date / Obs.	Oct. 7. 2012 13:54			Nov. 11. 2012 08:02			Dec. 27. 201208:03		
	Obs.	Image	Temperature difference	Obs.	Image	Temperature difference	Obs.	Image	Temperature difference
Incheon	22.00	19.97	**2.03**	5.30	3.10	**2.20**	2.50	0.70	**1.80**
Ansan	21.20	19.10	**2.10**	1.50	-0.70	**2.20**	-0.90	-3.70	**2.80**
Pyeongtaek	21.80	19.68	**2.12**	5.20	3.10	**2.10**	2.70	0.00	**2.70**



October 7, 2012 November 11, 2012 December 27, 2012

Figure 4. Temperature Comparison Graph between Observatory Data and Image Extraction

This result of the average temperature difference is judged to be caused by emissivity decrease due to the influence of the atmosphere.

3. Temperature Variant Analysis of Mt. Baekdu Cheonji lake

3.1. Data Acquisition

This study extracted the chronological surface temperature of Cheonji lake using Landsat ETM+ satellite images of 8 time periods from July 2000 to July 2010 to detect the temperature variant of Mt. Baekdu Cheonji lake. Figure 5 shows the target area, Cheonji lake and the neighboring area, and Table 4 shows the chronological features of the satellite images used for the study.

Figure 5. Target Area and Neighboring Area

Table 4. Satellite Image used in this Study

Date of shooting	SLC on/off	cloud (%)
Jul. 18, 2000.	SLC on	69
Jul. 29, 2004.	SLC off	38
Jul. 16, 2005.	SLC off	45
Jul. 19, 2006.	SLC off	39
Jul. 06, 2007.	SLC off	35
Jul. 22, 2007.	SLC off	15
Jul. 27, 2009.	SLC off	36
Jul. 14, 2010.	SLC off	71

The reason why July was chosen for temperature extraction period was to choose the time with the least influence by ice and snow which usually cover it from mid-October until mid-June next year as mentioned in the introduction.

To extract only Cheonji lake, the temperature extraction target area from the acquired satellite images, a mask band using ROI setting for the image with the least influence by cloud among the July images was generated. Using the generated mask band, only Band62, the thermal infrared band among Landsat ETM+ images for each period was masked. For images in which there is cloud above Cheonji lake, only areas excluding cloud were chosen to carry out the masking. This is because cloud affects emissivity and reduces the accuracy of temperature extraction value.

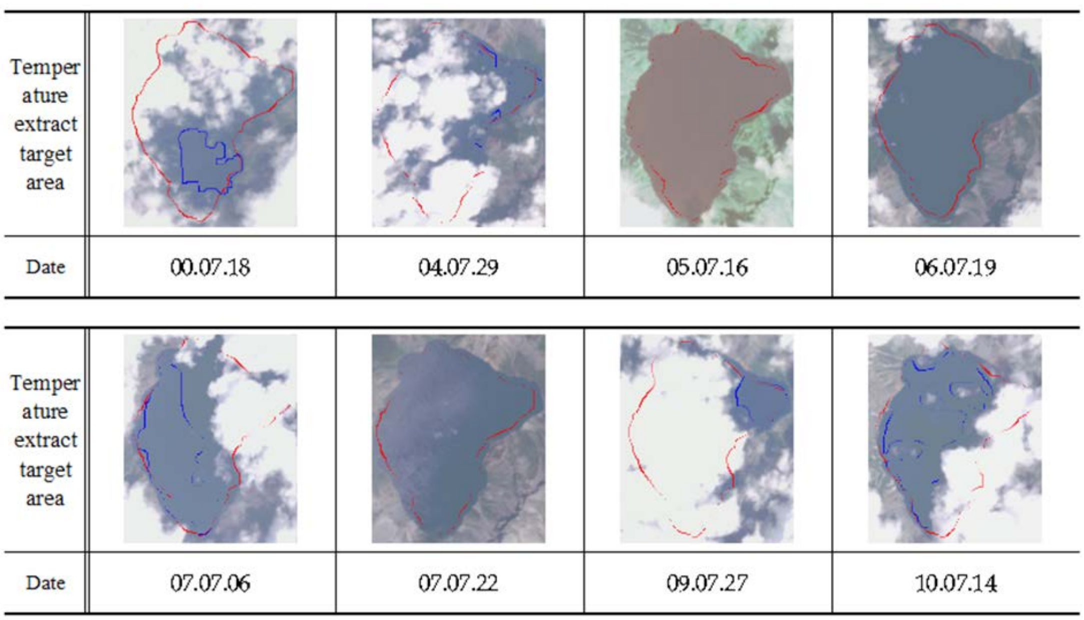
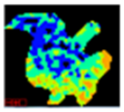
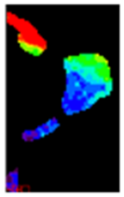
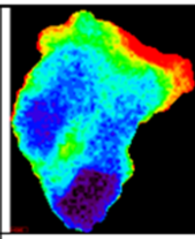
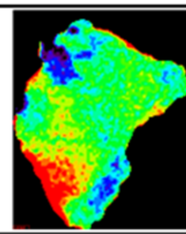
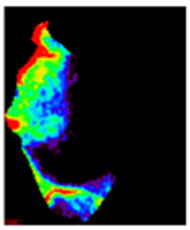
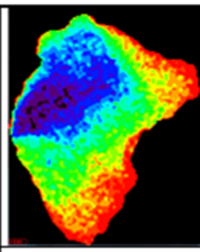
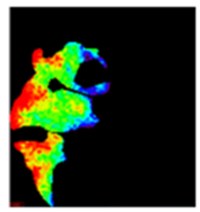


Figure 6. Temperature Extraction Target Area

3.2. Temperature Variant Analysis on Mt. Baekdu Cheonji Lake

As in this heading, they should be Times New Roman 11-point boldface, initially the parts excluding cloud were selected from each chronological image to extract temperature. Figure 7 shows the distribution of each chronological temperature extraction target area.

Temperature distribution				
Date	00.07.18	04.07.29	05.07.16	06.07.19

Temperature distribution				
Date	07.07.06	07.07.22	09.07.27	10.07.14

Temperature (℃)	
	over 8
	7~8
	6~7
	5~6
	under 5

Figure 7. Temperature Distribution in Temperature Extraction Target Area

As shown in Figure 7, there is one extracted temperature in each pixel, and this study organized and calculated the temperature value for each pixel to calculate the temperature of the target area. As a result, the temperature distributions were 6.16℃ in July 18, 2000; 8.24℃in July 29, 2004; 7.25℃ in July 16, 2005; 9.99℃ in July 19, 2006; 7.22℃ in July 6, 2007; 7.62℃ in July 22, 2007; 9.84℃ in July 27, 2009; and 9.30℃ in July 14, 2010, which are like the graph in Figure 8.

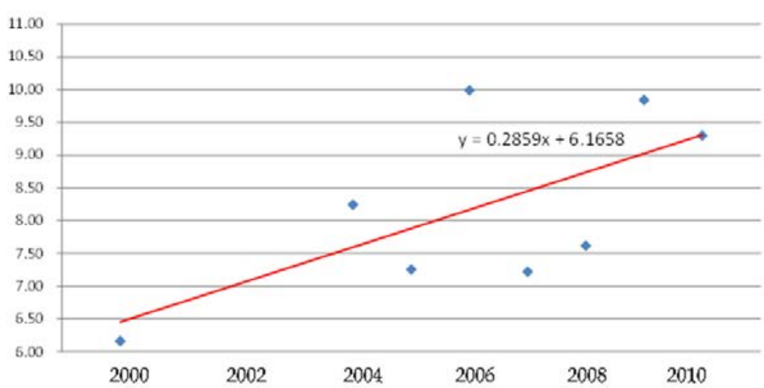


Figure 8. Temperature Variant Graph of Cheonji Lake

The temperature of Cheonji lake increased from 6.16℃ in July 2000 gradually to 9.84℃ in July 2009 and 9.30℃ in July 2010, up to approximately 10.00℃. Since these are temperatures extracted using satellite images, considering the results from comparison with the real temperature data in the section of investigation in this study, the actual average temperature of Cheonji lake is judged to be over 10.00℃. In addition, judging from the fact that the rising trend of the temperature increases at an inclination of approximately 0.236℃ a year, though Cheonji lake is difficult to access, it is judged that consistent indirect observation of the temperature variant of Cheonji lake using remote sensing technology is necessary. Also, through closer cooperative relationship with China, hourly measurement and management of Cheonji lake water temperature should be carried out. It is expected that this will be helpful for research on a recent issue of the predictions and possibilities of Mt. Baekdu volcanic eruption.

4. Conclusion

This study got the following conclusions as a result of obtaining satellite images through remote sensing technology in Mt. Baekdu Cheonji lake with a weak accessibility and extracting and analyzing temperature.

1.As a result of hourly temperature measurement to investigate the usability of Cheonji lake temperature extracted using Landsat ETM+ images, Koreas' tide station water temperature and temperature extracted from image form which values could be obtained were compared, which showed differences of minimum 1.80℃ to maximum 2.70℃, through that, usability was presented.

2. As a result of extraction of temperature of Cheonji lake using Landsat ETM+ images, average temperature has increased from 6.16℃ in 2000 to approximately 10.00℃ in 2009 and 2010 consistently, and considering emissivity decrease because of the influence of the atmosphere, the average temperature of the real Cheonji lake would be more than 10.00℃.

3. In the future, systematic investigation using hourly real data of Mt. Baekdu Cheonji lake water temperature will be helpful for predictions and possibilities related research on Mt. Baekdu volcanic eruption.

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