Statistical Atmospheric Correction of Lake Surface Temperature from Landsat Thermal Images

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ABSTRACT:

In this study, we analyzed surface temperature of lakes in the Han River system, using Landsat-5 and -7 time-series images. Surface temperature was extracted using NASA equation and compared with *in situ* 10m-depth temperature in Lake Soyang and surface temperature on five other dam lakes downstream. The 24 images out of 29 showed standard deviation of temperature difference less than 2℃, to which a novel statistical atmospheric correction could be applied. The correlation coefficients were 0.950 at Lake Soyang and 0.979-0.997 at the other lakes after atmospheric correction.

KEY WORDS: Landsat, *in situ* temperature, temperature difference, atmospheric correction

1. INTRODUCTION

Satellite thermal sensors can measure exact temperature of the target surface if it can detect only the emitted energy rather than reflected energy from the target. Water is close to black body which absorbs all the incident energy with no direct reflection, and emits all energy radiated from it. Therefore, daytime thermal infrared satellite imagery, such as Landsat-5 and -7 thermal bands, is very useful to measure the surface temperature of the water body with high spatial resolution. However, atmospheric interference has been an obstacle to this purpose.

In this study, we calculated surface temperature of the Han River system using NASA equation from Landsat TM, ETM+ images obtained from 1994 to 2004 and compared with *in situ* temperature. A novel statistical atmospheric correction method was investigated and applied to the time-series images of Landsat TM and ETM+.

2. STUDY AREA AND DATA

The study area is the six lakes of the Han River system: Lake Soyang, Paro, Chuncheon, Euiam, ChongPyong, Paldang (Fig 1). All lakes were made by construction of artificial dams, are called dam_lakes (Kim *et al.*, 2002). Lake Soyang is a lake-type dam-lake and the others are river-type dam-lakes (Kim *et al.*, 2003).

We used *in situ* water temperature data collected from 18 locations: one location at Lake Soyang, three at Paro, Chuncheon, Euiam and Chongpyong respectively, and five at Paldang. The *in situ* data has been measured at 10m-depth in Lake Soyang and at the water surface in other lakes, mostly once a month from 1992 to 2004.

Landsat TM, ETM+ images used in this study were 29 from PATH-ROW 115-034 and 116-034. Relatively many numbers of images could be used because the study area is covered by both adjacent satellite paths.

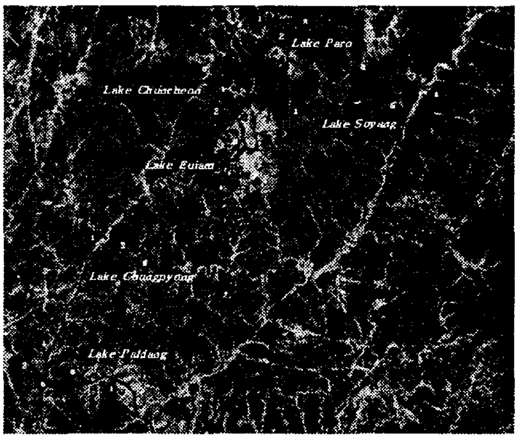

Fig 1. Study area

3. AT-SATELLITE TEMPERATURE CALAULATION AND COMPARED WITH *IN SITU* ITERPOLATED TEMPERATURE

At-satellite temperature of lake surface (T_{sat}) was calculated from Landsat thermal images (Chander and Markham, 2003), using NASA equation (Jeong and Yoo, 1998). They are compared with *in situ* lake temperature which was interpolated from the monthly measurement data ($T_{\mathrm{int}\,p}$). The relationship between T_{sat} and $T_{\mathrm{int}\,p}$ are shown in Fig 2. The temporal average ($\overline{\Delta T}_{temporal}$) of temperature difference (T_{sat} - $T_{\mathrm{int}\,p}$, ΔT), its standard deviation ($\sigma_{temporal}$), and the correlation coefficient (ρ) between $T_{\mathrm{int}\,p}$ and T_{sat} are also depicted in this figure. Outliers outside 2 $\sigma_{tempora}$ were removed.

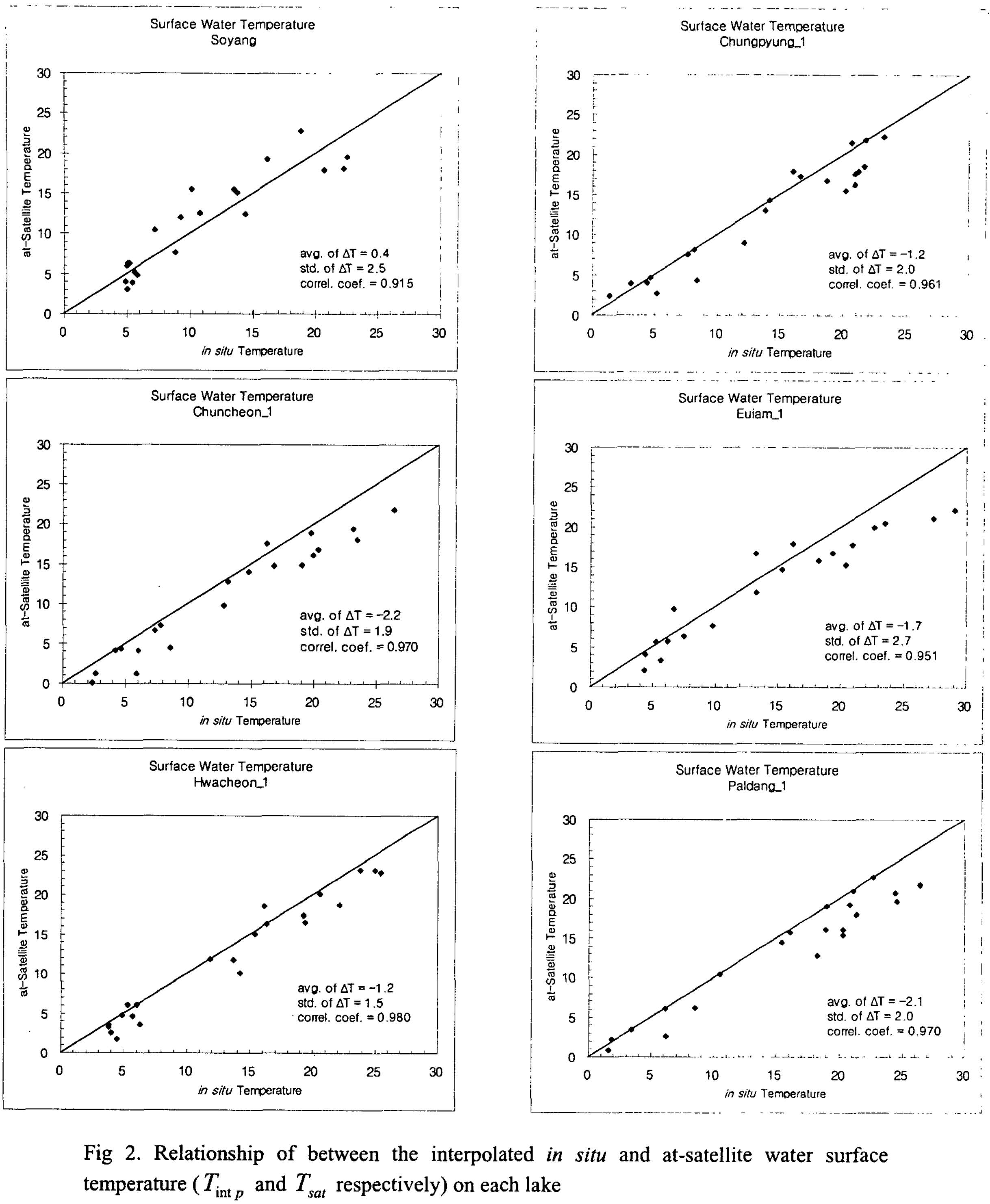

Fig 2. Relationship of between the interpolated *in situ* and at-satellite water surface temperature ($T_{\text{int}\,p}$ and T_{sat} respectively) on each lake

Although $T_{\text{int}\,p}$ is the value at the time of satellite acquisition by using interpolation from monthly observed ground measurement data, ρ shows relativity high such as 0.915 at Lake Soyang and 0.951-0.980 at other lakes. The value of $\Delta T_{temporal}$ is mostly negative because of atmospheric absorption from aerosol, dust, and cloud. To compensate for such atmospheric effect, we have developed a novel statistical atmospheric correction method as follows.

4. STATISTICAL ATMOSPHERIC CORRECTION

We evaluated the spatial average ($\overline{\Delta T}_{spatial}$) of dam-lakes and its standard deviation ($\sigma_{spatial}$), except for Lake Soyang whose in situ water temperature is not from the water surface.

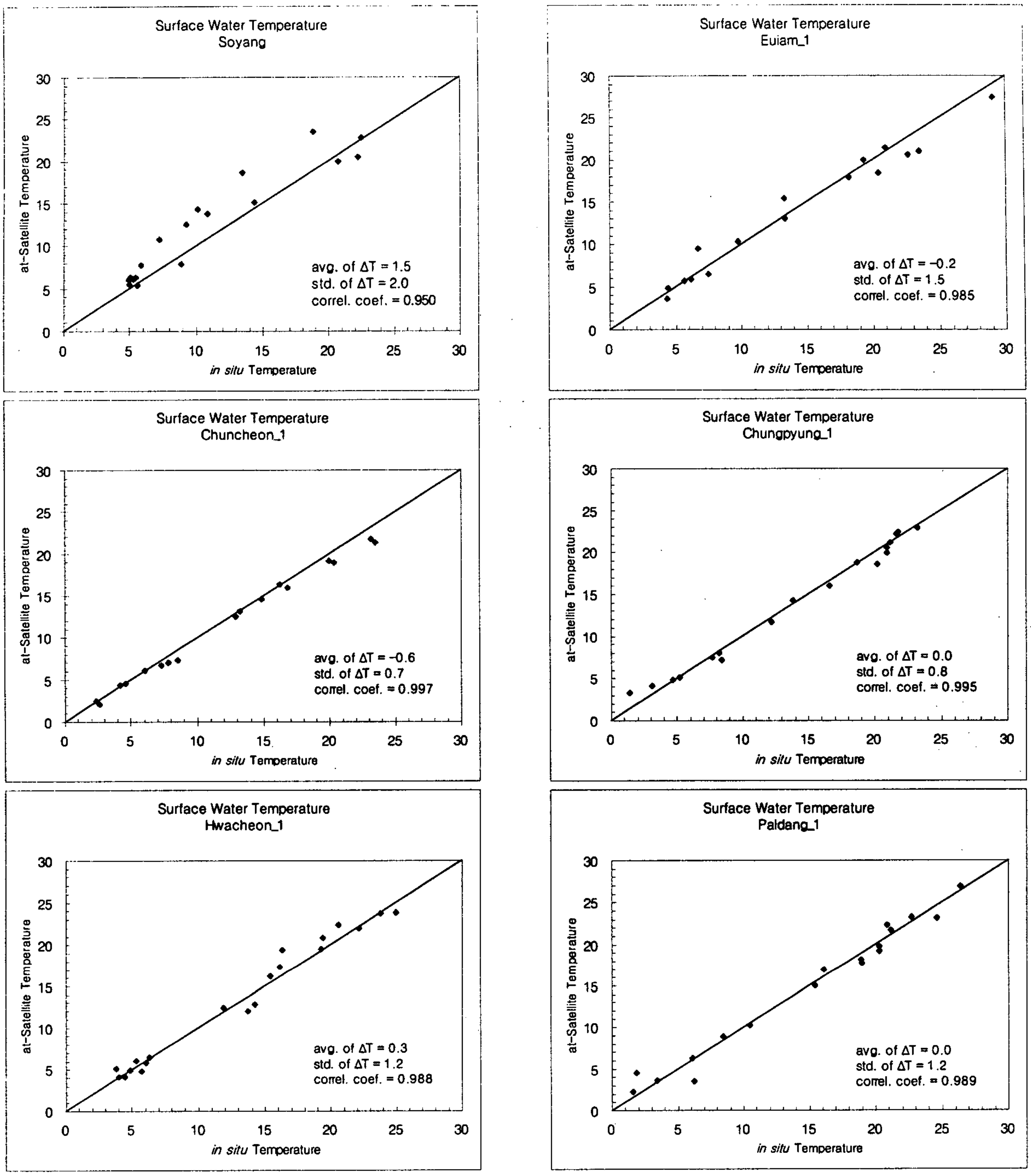

Fig 3. Relationship between the interpolated *in situ* and at-satellite water surface temperature ($T_{\text{int}\,p}$ and T_{sat}^{atmc} respectively) on each lake after applying statistical atmospheric correction

Images with high $\sigma_{spatial}$ indicate inhomogeneous distribution of vapour, dust and aerosol over the study area from which no statistical correction can be made. We can positively estimate atmospheric absorption temperature (T^{atm}) for 24 images of which $\sigma_{spatial}$ are less than 2.0℃.

$$T^{atm} = -\overline{\Delta T}_{spatial} \tag{1}$$

We then evaluated atmospherically corrected at-satellite water surface temperature (T_{sat}^{atmc}) and atmospheric corrected temperature difference (ΔT^{atmc}) using T^{atm} as follows:

$$T_{sat}^{atmc} = T_{sat} + T^{atm} \qquad (2)$$

$$\Delta T^{atmc} = \Delta T + T^{atmc} \qquad (3)$$

Note Lake Soyang was removed evaluating T^{atm} at equation (1), but atmospheric correction of equation (2) and (3) was applied to all lakes. The relationship between T_{sat}^{atmc} and $T_{\mathrm{int}\,p}$ is shown in Fig 3. The temporal average of temperature difference after atmospheric correction ($\overline{\Delta T}_{temporal}^{atmc}$) was 1.5℃ at Lake Soyang and shows evenly distributed values of -0.7-0.6℃ at the other lakes. Its standard deviation ($\sigma_{temporal}^{atmc}$) decreased and the correlation coefficient between $T_{\mathrm{int}\,p}$ and T_{sat}^{atmc} (ρ^{atmc}) has been generally improved to 0.950 at Soyang and 0.979-0.997 at other lakes. The high anomaly at Lake Soyang has been analyzed due to seasonal stratification (Lee, 1989), and was reported separately in [Lee and Han, 2005].

5. CONCLUSION

The at-satellite water temperature measured from 29 Landsat satellite images over lakes in the Han River observed from 1994 to 2004 shows relatively high correlation (0.915 at Lake Soyang and 0.951-0.980 at the other lakes) even though the interpolated *in situ* temperature data was used from monthly measurement. A novel statistical atmospheric correction applied to 24 images improved the correlation coefficient to 0.950 at Lake Soyang and 0.970-0.997 at other lakes. This result proves that statistical atmospheric correction method is of avail sufficiently. This statistical atmospheric correction method can be applied to other water body where there are temporally and spatially abundance in satellite thermal images and *in situ* data.

6. ACKNOWLEDGE

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7. REFERENCE

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