Evaluating Thermal Comfort in City and its Relation to Socio Economic Activities

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Abstract: In this study, we developed methods for calculating Wet Bulb Globe Temperature (WBGT) and Wind Chill Temperature (WCT) from Multi-functional Transport Satellite (MTSAT) data (IR1~IR2), and tried to improve the methods, so that we can evaluate thermal comfort in Asia-Pacific region by satellite remote sensing in near real time. As a result, it was found that our WBGT formula could express the tendency of WBGT change and detect the risk value (WBGT over 25). That enabled making thermal comfort image mappings in 4km resolution. About formula of WCT, we needed further study to get accuracy. In addition, as one of the indices of socio economic activity, we examined the relationship between WBGT and GDP per capita of each country in this study. As a result it was found that high WBGT countries tend to have low GDP per capita. From this research, hourly evaluation of thermal comfort in whole hot area and its visualization became possible, and the database from this calculation would be useful in analyses about relationships between thermal comfort and socio economic activities.

Introduction

Urban environmental assessment is one of important issues for remote sensing now. For example, heat island is one of the urban problems in cities. For evaluating its effect, algorithms for land surface temperature retrieval from satellite have been developed[Oyoshi et. Al, 2009]. However, human's health and thermal comfort are affected by not only the temperature but also other factors including humidity, wind speed and solar radiation. So we usually use composite temperatures, which are indexes expressing sensible climate, for assessing environment. In this study, we developed methods for calculating WBGT(for hot season) and WCT(for cold season). It is useful for evaluating thermal comfort in city life in large area in real time. In addition, regional thermal comfort's relevance to various statistical data about social life could be examined.

What is **WBGT** (**W**et **B**ulb **G**lobe **T**emperature)?

・estimate the effect of temperature, humidity and radiation on humans
・determine appropriate exposure levels to high temperature and prevent from heat disorder

WBGT (outdoor) = 0.7Tw + 0.2Tg + 0.1Td

Where Tw=wet bulb temperature
Tg=globe temperature
Td=dry bulb temperature
(C.P.Yaglou and D.Minard, 1957)

Simple estimate formula:
WBGT = 0.7Tw + 0.4Td – 1.4
Cf. Tg and Td,"Tg=1.45Td-7.09" (Niigata Agricultural Research Institute,2004)

Table1:Risk level of heat disorder

WBGT(℃)	Level*
>31	Danger
28-31	Alert
25-28	Advisory
21-25	Caution

*by Japan Amateur Sports Association(1994)

What is **WCT** (**W**ind **C**hill **T**emperature)?

・calculate the dangers from winter winds and freezing temperatures

$$WCT = 13.12 + 0.6215 \cdot T - 11.37 \cdot V^{0.16} + 0.3965 \cdot T \cdot V^{0.16}$$

Where T=air temperature(℃) / V=wind speed(km/h) (Siple and Passel, 1941)

Table2: Risk level of frostbite

WCT	Level
-10 - -27	Low
-28 - -39	Risk: exposed skin can freeze in 10 to 30 minutes
-40 - -47	High risk: exposed skin can freeze in 5 to 10 minutes
-48 - -54	Very high risk: exposed skin can freeze in 2 to 5 minutes

Methodology

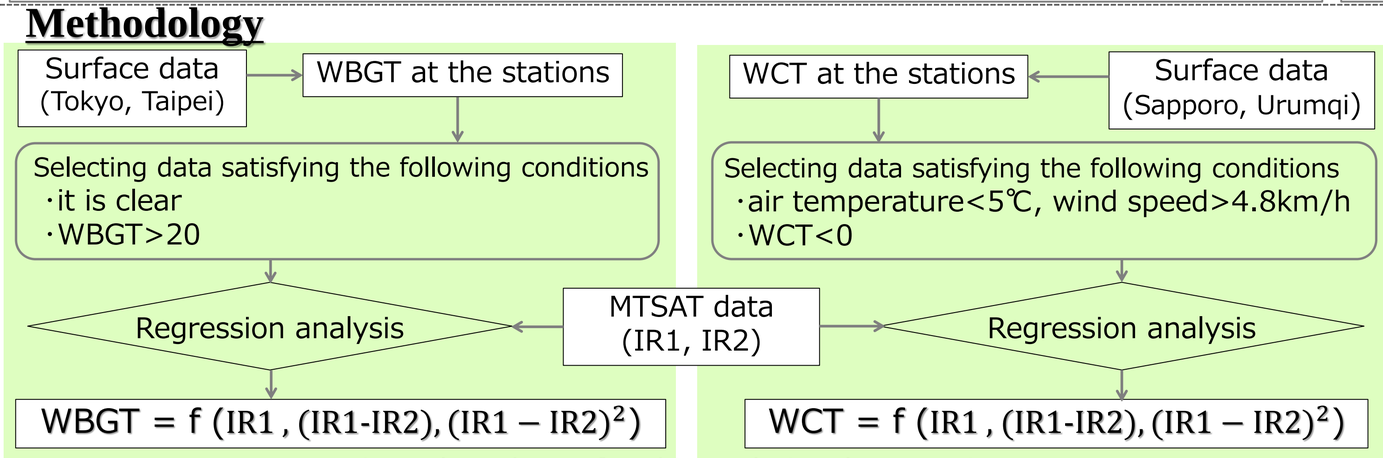


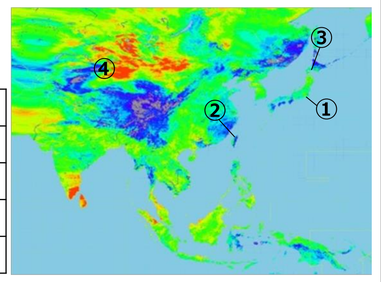
Fig.1 Flow chart of making relational expressions

< Data used in this study >

Surface data downloaded from NNDC Climate Data Online (http://hurricane.ncdc.noaa.gov/pls/plclimprod/cdomain.abbrev2id)

Table3 : station data

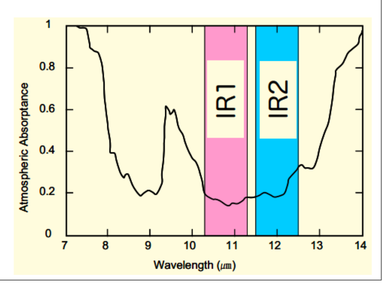
	Station	①Tokyo	②Taipei	③Sapporo	④Urumqi
	Latitude	35.683	43.06	25.033	43.8
	Longitude	139.767	141.329	121.517	87.65
	Data	hourly	3 hourly	Hourly	3 hourly
		2011/1/1— 2011/12/31			



MTSAT thermal infrared data(IR1 and IR2 channels) archived by IIS, The University of Tokyo (http://webgms.iis.u-tokyo.ac.jp/)

Table4: MTSAT technical specifications

Channel	Wavelength	Spatial Res.
IR1	10.5-11.5μm	4km
IR2	11.5-12.5μm	4km
IR3	6.5-7.0 μm	4km
IR4	3.5-4.0 μm	4km
VIS	0.55-0.90 μm	1km



Results

The following relational expressions were derived as the results.

$$WBGT = 0.0209IR1 + 2.58(IR1-IR2) - 0.272(IR1-IR2)^2 + 16.1 \quad \cdots(1)$$

$$WCT = 0.0788IR1 + 1.95(IR1-IR2) - 0.149(IR1-IR2)^2 - 29.6 \quad \cdots(2)$$

Fig.2～3 show annual change of WBGT(in Tokyo) and WCT(in Sapporo). "satellite" is calculated from (1)(2).

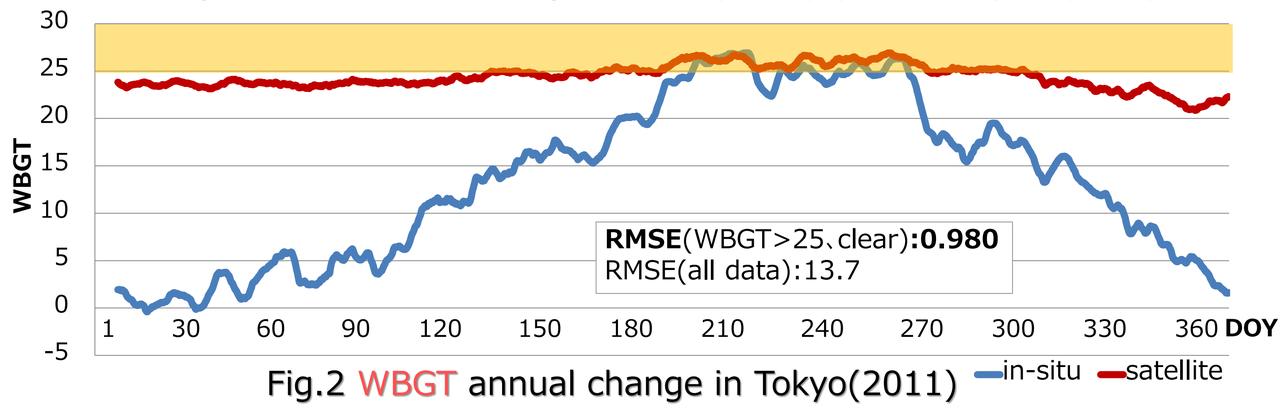


Fig.2 WBGT annual change in Tokyo(2011)

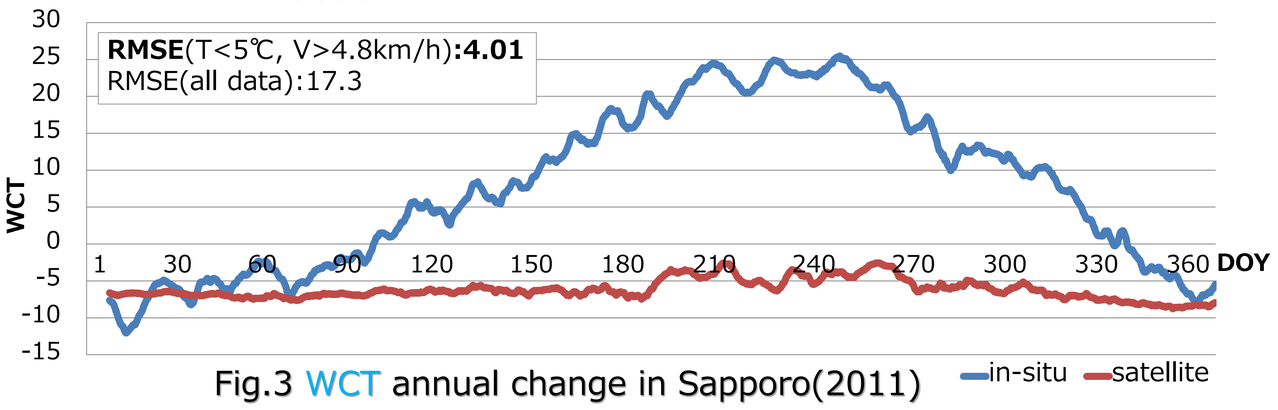


Fig.3 WCT annual change in Sapporo(2011)

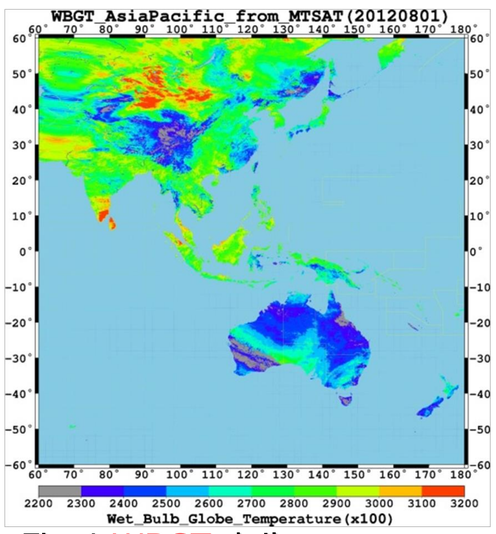


Fig.4 WBGT daily mean map (2012.8.1)

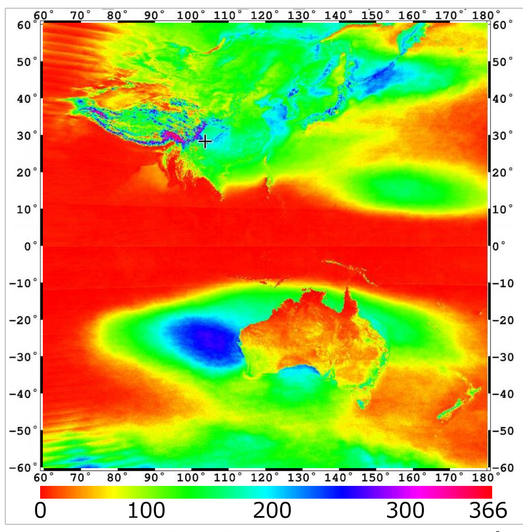
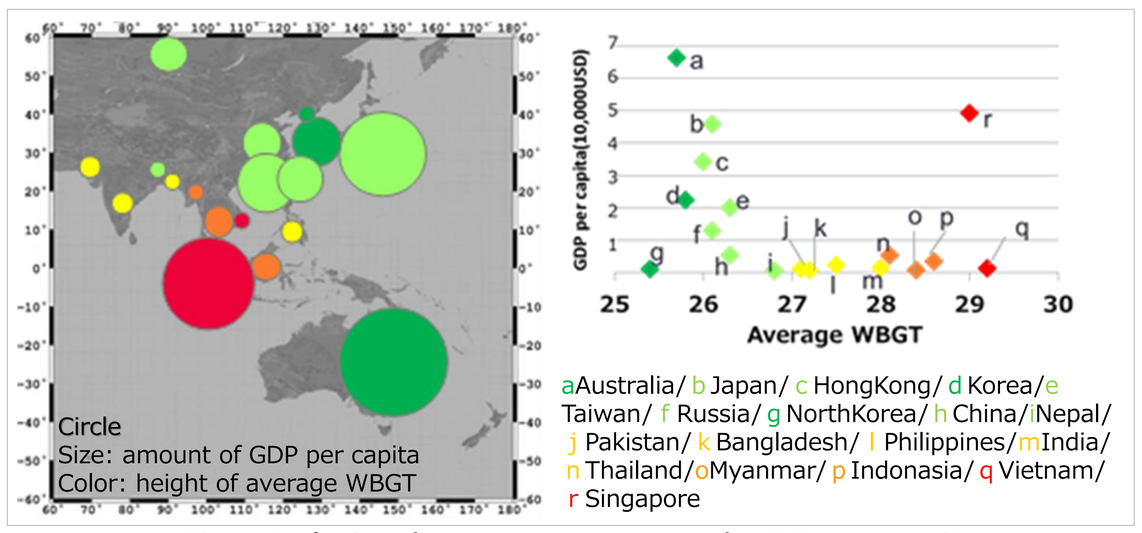


Fig.5 Average annual days when WBGT takes critical value

Fig.5 shows average annual days (2007~2012) when WBGT reaches 25.

Table5:the number of days in cities

CITY	LAT	LON	
Sapporo	43.1	141.3	185
Tokyo	35.7	139.8	225
Seoul	37.6	127.0	244
Taipei	25.0	121.5	235
Bangalore	13.0	77.58	362
Bali	8.22	115.8	365



aAustralia/ b Japan/ c HongKong/ d Korea/ e Taiwan/ f Russia/ g NorthKorea/ h China/ i Nepal/ j Pakistan/ k Bangladesh/ l Philippines/ m India/ n Thailand/ o Myanmar/ p Indonasia/ q Vietnam/ r Singapore

Fig.6 Relation between WBGT and GDP per capita

Conclusion

●It can be said that WBGT formula(1) can be applied to the data when WBGT is over 25.(Fig.2) We could evaluate thermal comfort in hot season by number of days when WBGT takes critical value(over 25) of each city by satellite remote sensing.(Fig.5)
●WBGT image mappings can be made in 4km resolution.(Fig.4)
●As the result of the examination into relation between WBGT and GDP per capita, it can be said that high WBGT countries tend to have low GDP per capita.(Fig.6)

Future works

●further study for getting accuracy of WCT formula
●further analyses of regional thermal comfort's relevance to various statistical data about social life

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