CONSTRUCTION OF A GLOBAL ENVIRONMENT DATABASE FROM SATELLITE REMOTE SENSING DATA - ESTIMATION OF AIR TEMPERATURE ON KYUSHU ISLAND, SOUTHERN JAPAN, FROM LANDSAT TM DATA AND GROUND STATION METEOROLOGICAL DATA

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ABSTRACT:

The construction of an environmental database will become more important than ever for sustainable development of the global environment. For this purpose, the earth's surface temperature (Ts) was calculated using satellite (Landsat TM) data. Air temperature distribution was estimated by application of a Ts-air model to the Ts datafile. The development of cold air lakes in several areas such as the Mt. Aso, Unzen and Kirishima volcanos and some characteristics of air temperature distribution on Kyushu Island were examined.

KEYWORDS: Landsat TM, thermal IR, temperature, local climate, database

1. INTRODUCTION

Laborious work is inevitable for data input and the construction of a datafile by hand labor or man-machine interaction, and for file management of an environmental database. To obtain information on broad areas far from the ground monitoring station is important and practical for management of the global environment. Remote sensing is an efficient procedure for data acquisition in such areas. In this study, the author estimated air temperature from Landsat TM and ground station meteorological data. Cold air lakes were revealed in several broad areas based on this file. A cold air lake is a typical manifestation of temperature inversion. Such inversion has a bad effect on air pollution, especially in basin-like areas. Therefore, this study introduced a new procedure for research on air pollution and its influence.

2. METHOD

2.1 Estimation of Surface Temperature

Figure 1 shows a flow chart used for construction of a temperature datafile. First, brightness temperature is calculated using the equation produced by Goddard Space Flight Center (1984) for the processing of Landsat TM thermal IR data (Nov. 18, 1986, 21:25). This brightness temperature before atmospheric correction is not an accurate value at the earth's surface. The most primitive but reliable method for correction of this brightness temperature is the application of a linear regression model derived from the Landsat brightness temperature and surface temperature (Ts) of the same target with a large dynamic range. Nevertheless, observation of surface temperature has not yet become routine. Therefore, the author used the value of water temperature near the surface observed for fishery resources and water use by some organizations such as the Maritime Safety Agency, Meteorological Agency, hydroelectric power plants, fisheries experiment stations and fishermen on fishing boats offshore.
The water has constant emissivity and a small temperature range among these several surrounding pixels. The satellite brightness temperature coincident with each observation point for seawater temperature was retrieved from the brightness temperature datafile. Then, the author developed a regression equation for correction of the brightness temperature by the observed seawater temperature and applied it to the brightness temperature datafile.

2.2 Estimation of Air Temperature

AMEDAS (Automated Meteorological Data Acquisition System) of the Meteorological Agency is a well constructed system for weather observation in Japan. This system can be used for the collection of air temperature data. Data points of surface temperature retrieved from the Ts datafile coincide with the location of AMEDAS weather stations. The calculated average value for two sample data obtained from AMEDAS was also coincided with that of Landsat observations. Then, a regression equation for estimation of air temperature was derived. Figure 2 shows a scatter map of AMEDAS air temperature and surface temperature. As the correlation coefficient between these two variables is 0.799, air temperature can be estimated from the Landsat Ts data. Though the estimation is based on a statistical procedure, air temperature can be estimated from surface temperature. The standard error of residuals for the equation is 1.91. The following equation (Eq.1) was obtained for this Ts-air equation. Therefore, the surface temperature derived from Landsat thermal data can be subjected to extrapolation for spatial analysis of air temperature.

$$Tair = 4.676 + 0.6007\ Ts \quad ....(1)$$

Standard error of residuals = 1.91

Where Tair is air temperature (°C), Ts, surface temperature (°C), number of samples, 51.

3. DEVELOPMENT OF COLD AIR LAKE

It is natural that air mass should obtain thermal energy from the earth's surface by heat transfer, radiation and convection through an air layer 1.5 m thick. Therefore, air temperature at 1.5 m height from the ground surface is determined by spatially averaged thermal radiation from the earth's surface. The temperature of the air varies with that of the earth's surface, and changes in the former lag behind those of the latter. This is obvious from theoretical analysis of one-dimensional heat transfer. Therefore, the inversion of surface temperature is antecedent to that of air as the temperature falls from night to morning. Ts and air temperature derived from satellite remote sensing data are important parameters for studies of local climate and its regional differences. The distributions of the surface and air temperatures on Kyushu Island, Southern Japan, thus obtained are shown in Photographs 1 and 2, respectively. The development of local climatic features such as cold air lakes, and regional differences in these phenomena for most of Kyushu have been clarified.

3.1 Aso Volcano

Photographs 1 and 2 show that the surface and air temperatures on the mid-slope of the central cone and the surrounding crater wall of Mt. Aso are higher than these of the atrio and slopes of somma. Some aspects of the spatial development of surface temperature may be affected by the type and degree of vegetation cover and differences in soil moisture. For example, the temperature of thinly vegetated areas such as grassland, dead *Eulalia* and bare soil is lower than that of other forms of land cover.

The inversion of air temperature was observed from two meteorological monitoring points, the Asosan (central cone; 1143 m) and Asokurokawa (atrio; 534 m) weather stations (Table 1), and inversion of surface temperature was observed in the area of Aso volcano. The development of surface temperature inversion, mentioned above, is similar to that of air temperature derived from the meteorological station.

3.2 Unzen Volcano

The inverse distribution of surface temperature is generally indistinct in the Unzen volcano (Shimabara peninsula). As a whole, the surface temperature decreases with increased altitude on the slopes of mountainous areas of Shimabara peninsula. Nevertheless, the inversion phenomenon is obvious between Mt. Kinugasa (849 m) and the Unzen resort area (678 m). Several small basin-like areas such as Unzen, Tashirodaira and Ikenotaira in the vicinity of the summit of the Shimabara volcano show inversion of Ts. As shown in Table 2, the temperature inversion in the area developed in the early morning of the following (Nov., 19, 1986). Therefore, it is clearly observed that the inversion of surface temperature precedes that of the air temperature.

3.3 Kirishima Volcano and its Surrounding Areas

The inverse distribution of air temperature is generally distinct in and around the Kirishima volcano. There is no ground monitoring station on the summit or on the mid-slope of the mountain. Nevertheless, the inversion phenomena of Ts is obvious between Mt. Kirishima (1574 m) and its surrounding basin areas (Okuchi basin: 150-200 m, Kakuto basin: 250-300 m, Kobayashi basin: 200-300 m).

Inversion of surface temperature also developed in and around some peaks such as Mt. Karakuni, Mt. Ebino and Mt. Nakatake, which showed a smaller relative height than areas in the vicinity of this whole volcanic area. The distribution of air temperature derived from Ts also shows the temperature inversion in this area, which was investigated by Yoshino (1961) using temporary data from forestry meteorological observations.

Both inversion phenomena of air temperature and Ts are more obvious in and around Mt. Aso than in the areas of the Unzen and Kirishima volcano.

3.4 Distribution of air temperature on Kyushu Island

In southern Kyushu, the air temperature of the Miyazaki plain is about 10 ℃. The distribution of a warmer belt (11 - 12 °C) of air temperature is observed in the middle of mountain slopes or middle lower slopes of southeast- and south-facing slopes of the Kyushu mountains. Similar warmer belts also develop in areas such as Mt. Seburi and the Chikushi Mountains in northern Kyushu. The altitude of these warmer belts on the mountain slopes varies with the location. Even if it varies with meteorological conditions, warmer belts with some fluctuations of altitude might develop on these mountain slopes.

Furthermore, mountain slopes facing the sea show relatively warmer areas than on the opposite side. This is caused by the influence of sea water temperature and temperature inversion.

Regional differences in the development of cold air lakes among these areas is caused by local situations such as distance from the sea, existence of surrounding seawater and slopes facing the Japanese current (*Kuroshio*) to the east and south. Sasakura and Watanabe (1958) described the influence of seawater on the distribution of air temperature in central Japan. We can also confirm its influence by visualization of the temperature distribution from satellite remote sensing.

4. CONCLUSIONS

In this study, the author has estimated the surface temperature from Landsat thermal IR data and sea truth temperature data. For the extrapolation of air temperature estimates, a model was successfully developed using the Ts datafile and AMEDAS air temperature data. Then regional differences in air temperature distribution and the development of local climates especially cold air lakes, in some areas such as Mt. Aso volcano, Mt. Unzen and Kirishima was investigated. Differences in temperature distribution on Kyushu Island are caused by the Japanese current and distance from the sea. Warmer belts of air temperature on mountain slopes were also examined.

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(# denotes the papers without any English title and abstract; J, in Japanese, JE, Japanese with English abstract)

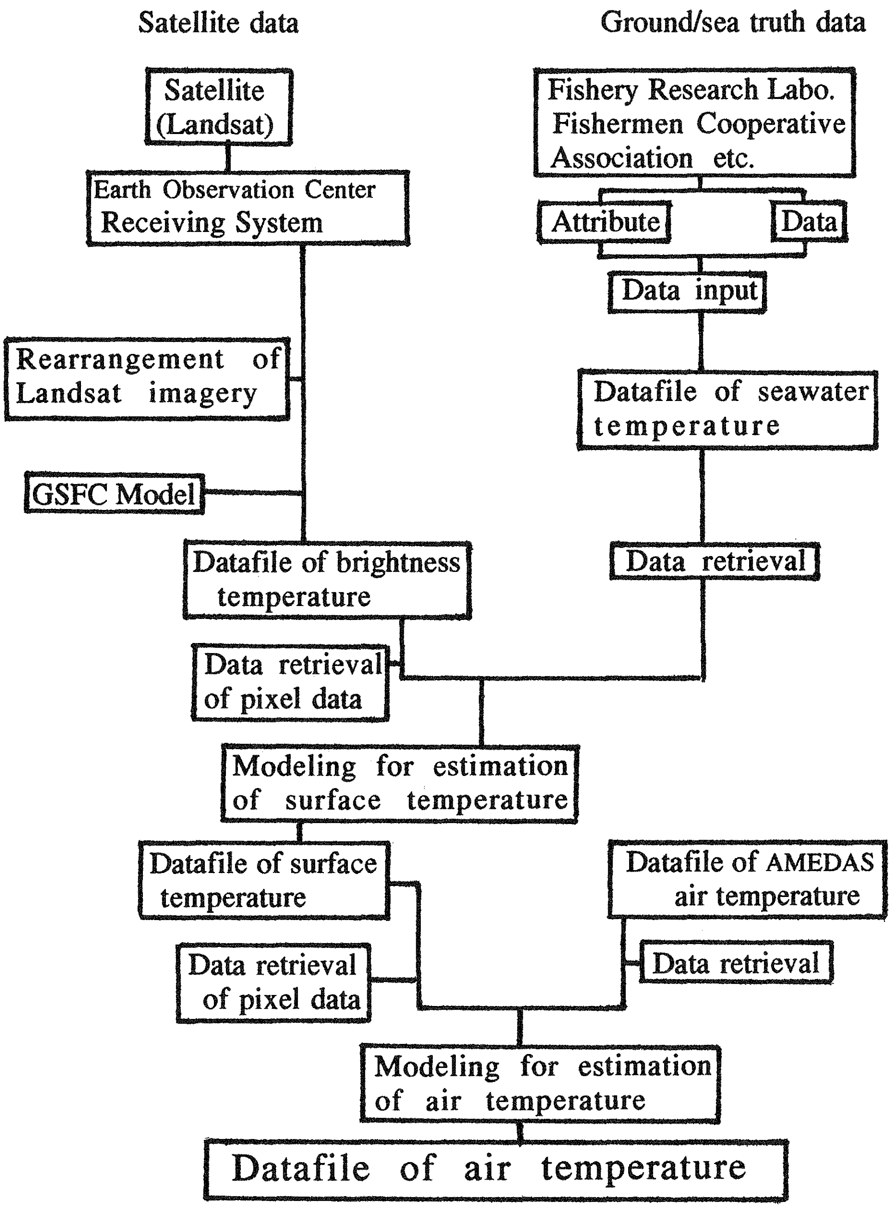


Figure 1 Flow chart for construction of air temperature datafile

Table 1 Temperature, wind speed and direction based on AMEDAS and report of monitoring station (Nov. 18, 1986)

Name of station (Height)	Unzen 690m	Kinugasa 849m	Shimabara 17m	Kuchinotsu 10m	Saga 4m
Temperature (℃)	6.2	5.5	(12.6)	(10.5)	10.8
Wind speed (m/S)	0	3	3	0.5	1.4
direction		NE	WNW	N	NNE

Name of station (Height)	Minamioguni 440m	Asosan 1143m	Asokurokawa 534m	Takamori 551m
Temperature (℃)	4.0	((5.0))	4.4	4.7
Wind speed (m/S)	1	0.2	1	0
direction	SSW		SSW	

Name of station (Height)	Miyazaki 6m	Nobeoka 19m	Aburatsu 3m	Nishimera 250m	Kakuto 228m
Temperature (℃)	11.4	9.0	11.9	(6.8)	(5.8)
Wind speed (m/S)	1	1	7	0	0
direction	NW	WSW	NNW		

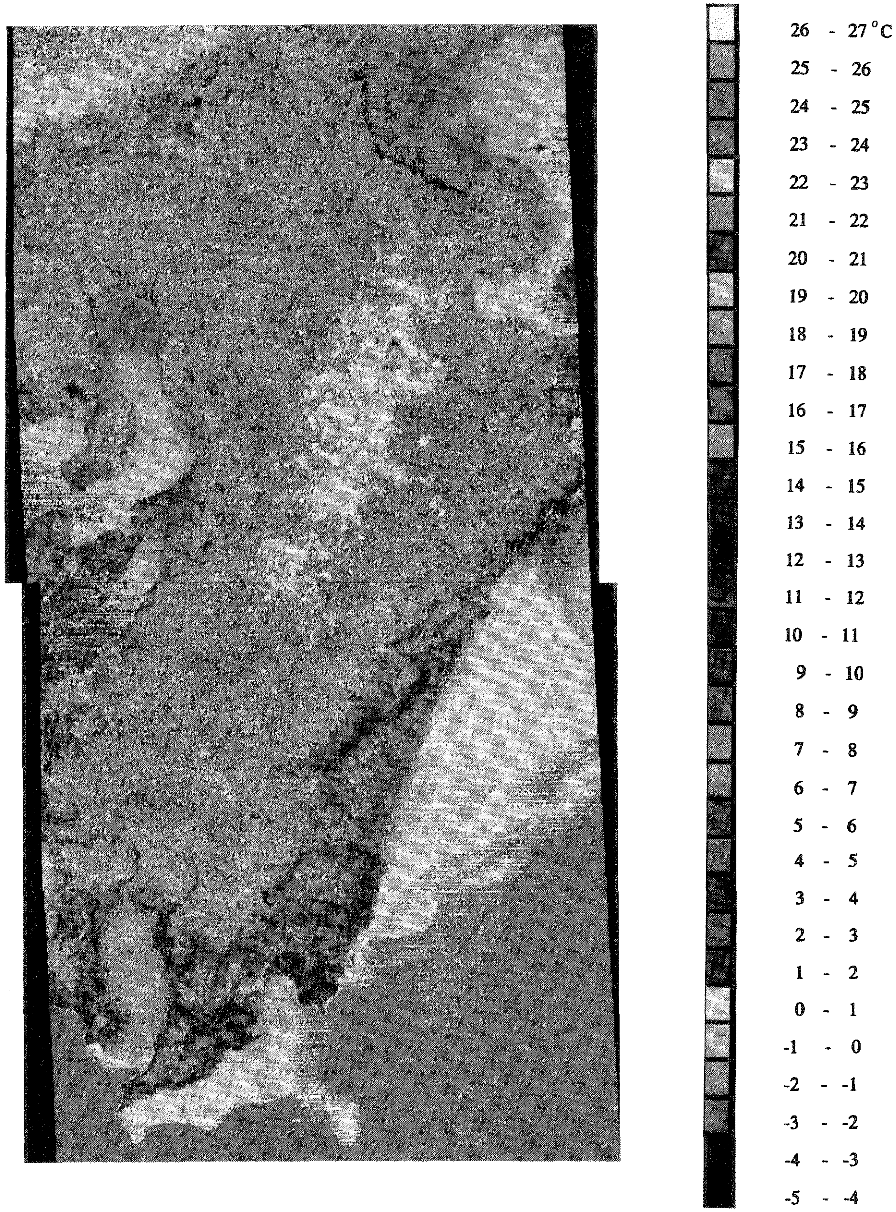
Name of station (Height)	Kobayashi 200m	Makinohara 384m	Kagoshima 4m	Okuchi 175m	Miyanojo 30m
Temperature (℃)	(8.5)	8.8	11,5	(4.4)	7.5
Wind speed (m/S)	(1)	0	2.3	0	0
direction	N		NNW		

Name of station (Height)	Akune 40m	Yatsushiro 8m	Hitoyoshi 146m	Ue 166m
Temperature (℃)	11.2	9.7	(6.8)	5.9
Wind speed (m/S)	2.9	1	0	0
direction	ESE	ESE		

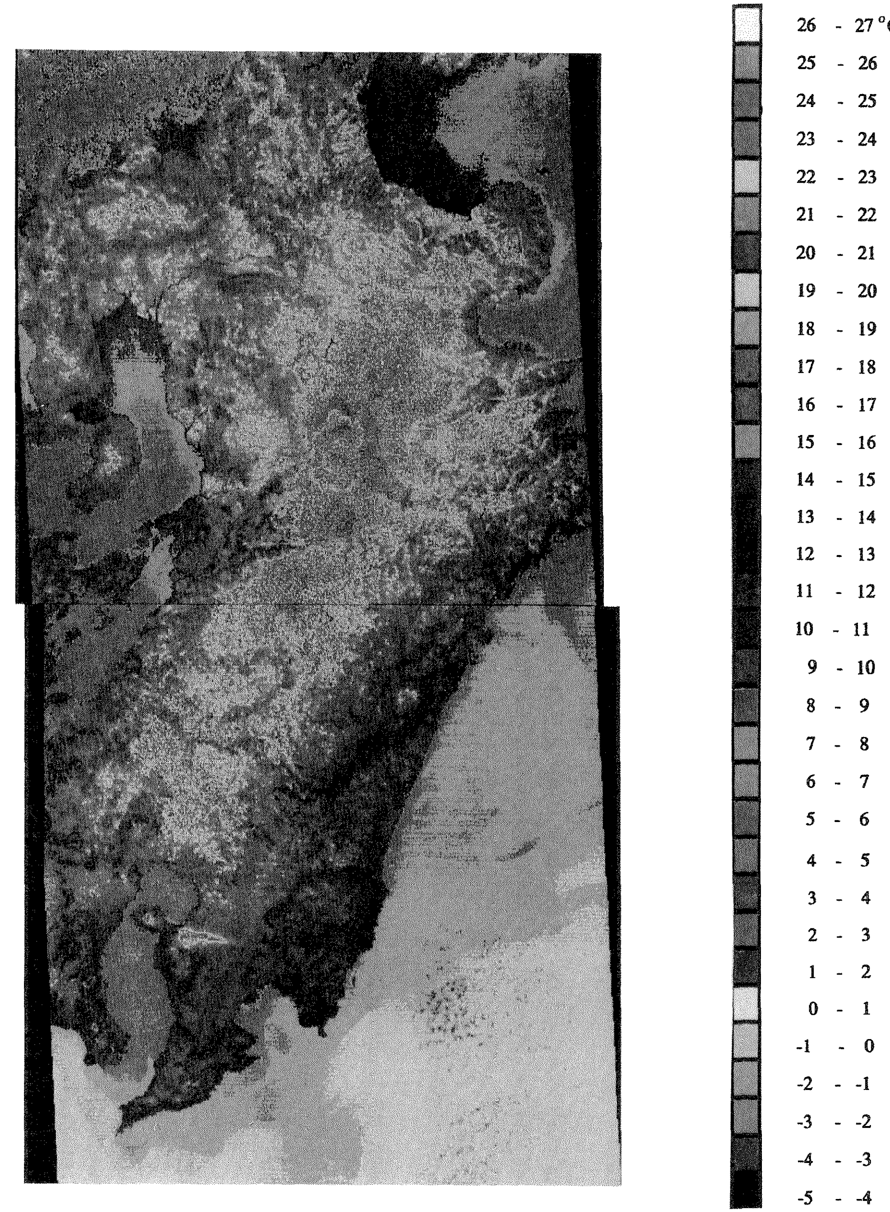
(): Average of the value obtained at 21:00 and 22:00
(()): Value obtained at 21:00

Table 2 Temperature variations from 18 to 19, Nov. 1986. (Unit; °C)

Date (Height)	Time	Unzen 690m	Kinugasa 849m	Asokurokawa 534m	Asosan 1143m
	5:00	4.0	6.2	0.2	
	6:00	3.8	6.6	0.2	7.4
	9:00	7.8	6.8	5.5	9.1
11/18	12:00	13.3	11.0	14.7	11.4
	18:00	9.1	6.2	8.1	6.5
	21:00	6.4	5.2	4.7	5.0
	21:30	6.2	5.5	4.4	
	22:00	6.0	5.9	4.2	
	0:00	5.7	6.0	3.4	4.3
	3:00	5.3	5.6	3.9	4.5
11/19	5:00	4.6	6.1	3.3	
	6:00	4.8	6.8	2.3	3.6
	9:00	8.1	9.7	8.5	4.9
	12:00	11.5	12.0	13.6	8.2



Photograph 1 Distribution of Surface Temperature of Kyushu Island (21:25, Nov. 18, 1986)



Photograph 2 Distribution of Air Temperature on Kyushu Island (21:25, Nov. 18, 1986)