THE RELATIONSHIP BETWEEN SST MEASUED FROM ATSR TO THE SPATIAL AND TEMPORAL BEHAVIOR OF OCEAN SKIN TEMPERATURE AS OBSERVED WITH AN IS SITU THERMAL INFRARED CAMERA

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ABSTRACT

During the MUBEX observation campaign, a thermal infrared camera (TIC) was mounted on a stage of a vessel to observe the behavior of sea skin surface temperature. The total number of images collected in the last two years is about 85,000. The distribution pattern of sea skin surface temperature is very changeable depending upon weather and sea state conditions. After describing about MUBEX and the calibration method of TIC, typical TIC data collected in MUBEX/96 were introduced.

1. INTRODUCTION

Mutsu Bay is located in the northern end of Honshu island of Japan as in Figure 1 . In the bay, a buoy system called Mutsu Bay Automatic Marine Monitoring Buoy System (MBAMMBS) is under operation by Aomori prefecture government. It is composed of four moored buoys and each buoy measures sea surface temperature (SST) at 1 m depth every hour on the hour, which provides match-ups for validation with excellent temporal and spatial coincidence. Around the bay, there are five meteorological stations and one radio sonde station. By using the data collected by those sophisticated observation systems, Yokoyama et al. have been engaged in validation for the accuracy of SST estimated by NOAA/AVHRR data (Yokoyama et al, 1991, 1993). They got SST estimation functions, of which standard deviation of errors is around 0.35 deg.C, and pointed that match-ups in midday under calm condition are usually accompanied with large errors. A special device to observe a fine structure of vertical temperature distribution near the sea surface was developed to prove a phenomena called sea surface effect (SSE) such that the water temperature in shallower layers steeply increases under calm and strong sunshine condition (Yokoyama et al, 1995, 1996). This result suggested that SSE is an another cause of errors than atmospheric effect and skin effect. In order to improve errors in SST estimation, the temporal and spatial behaviors of water temperature near surface must be investigated more detail.

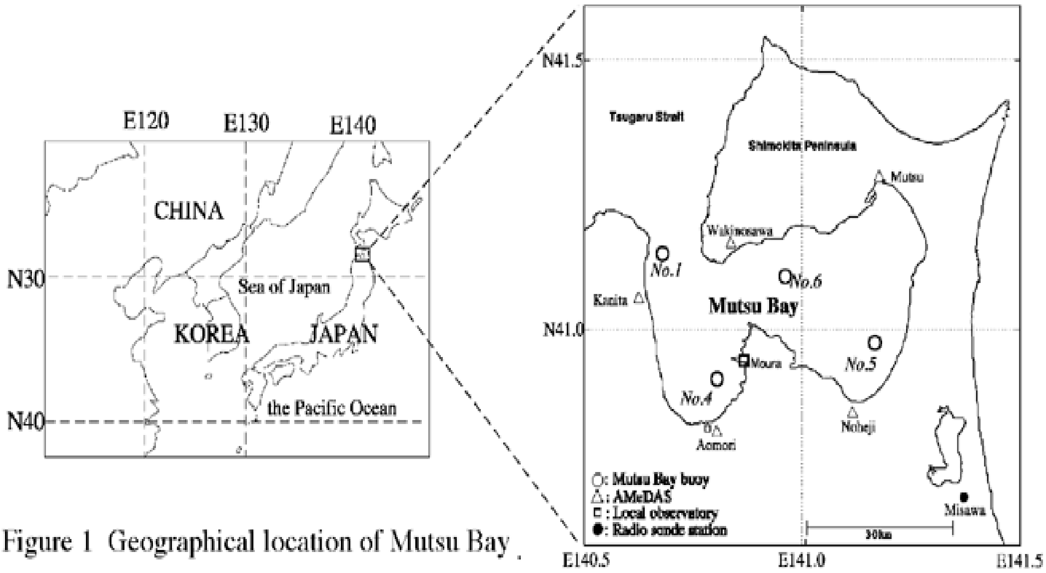
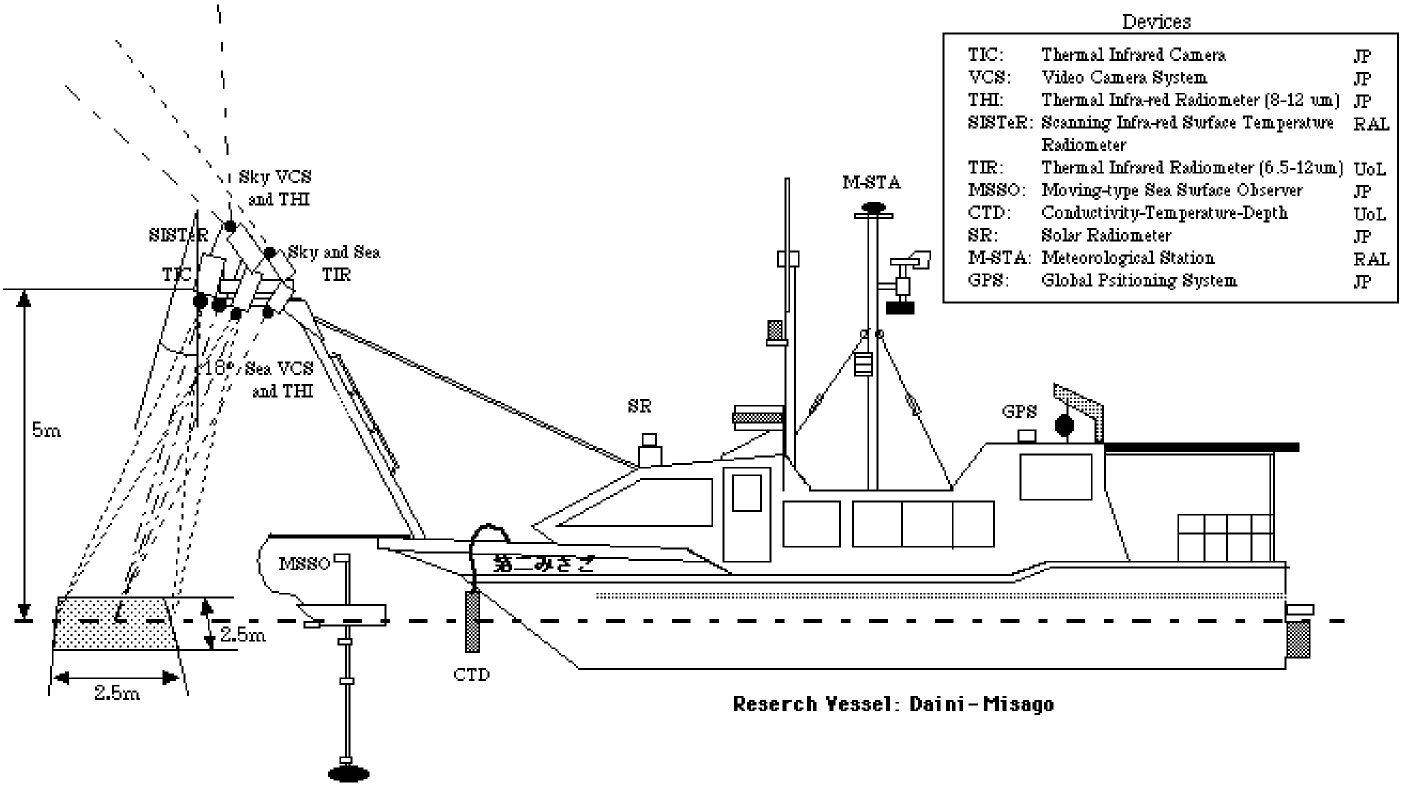


Figure 1 Geographical location of Mutsu Bay

MUBEX (MUtsu Bay sea surface temperature validation Experiment) is a Japan-UK joint research project to validate the accuracy of SST estimated by satellite and to investigate the physical behavior of heat exchange at the ocean surface. It was organized by Prof. Yokoyama and Prof. Llewellyn-Jones, and started in 1995 as a three year project.

2. OUTLINE OF MUBEX OBSERVATION IN CAMPAIGN

MUBEX campaign has been held in summer season. We prepared a special vessel equipped with devices to observe spatial and temporal behaviors of sea skin temperature. Figure 2 shows the schematic view of the instrumentation. In the campaign of 1995 and 1996, the vessel has been conducted data collection at overpass of ERS-1 & -2, NOAA-12 & -14, but ADEOS will be added in MUBEX/97 campaign.



Figue 2 The schematic view of the instrumentation on the research vessel of MUBEX'96

Table 1 Specifications of the TIC

temperature range	-20 ~ +80 deg.C
temperature resolution	0.075 deg.C
wave length	8 ~ 13 micro m
IFOV	1.5 mrad
FOV	(H) 30deg.x (V) 28.5deg.
scanning mode	Image mode Line mode
flame time	0.8 sec/flame
image size	255pixel x 207line

A thermal infrared camera (NEC San-ei TH3102), of which catalog specifications are shown in Table 1, was installed on the stage at 5 m above the sea surface in the bow. One frame of TIC image is composed of 255 pixels by 207 lines, and one pixel resolution from the height of 5 m is about 1 cm square.

At calibration, TIC image was found to be accompanied with three major noises as follows.

(1). Line noise: This is a stripe-type noise appearing in the horizontal direction with the amplitude of 0.1 deg.C. This is caused by mechanical vibration of a cooling pump for detector. For this correction, each image was applied spatial Fourier transform to exact the noise components, and a noise-free image was recovered after applying inverse Fourier transform. Figure 3 shows an example of images before and after the correction.

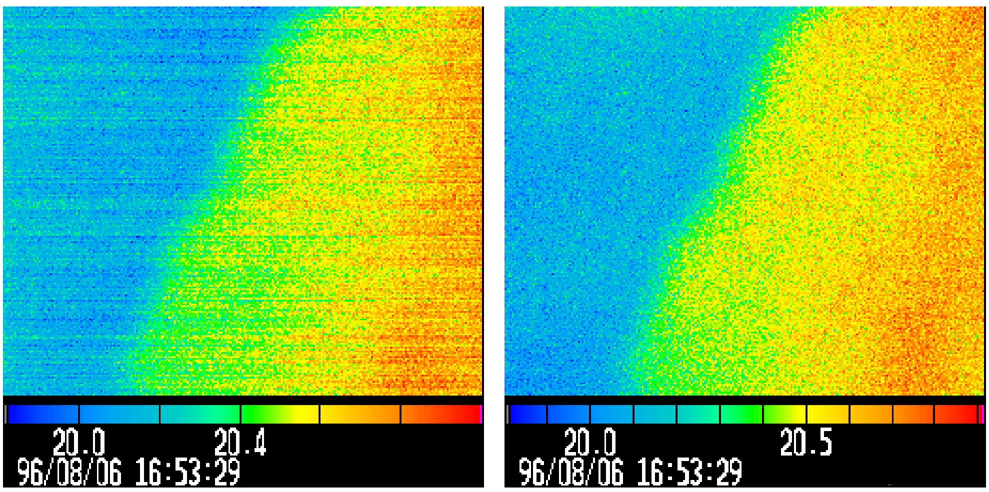


Figure 3 An example of image before and after a stripe-type noise correction.

(2). Spatial distortion of sensitivity: The detecting sensitivity of TIC is not spatially homogenous due to electro-magnetic induction from scanning mirror driving. The sensitivity degrades gradually from the center to the edge of frame. By looking spatially homogeneous temperature target, the temperature difference between the center and the edge was evaluated about 0.1 deg.C. For the correction, a function for compensating the spatial sensitivity distortion was developed.

(3). Quantization noise of reference blackbody temperature: The quantization step of the reference blackbody temperature is 0.1 deg.C. At each step change of the reference, the detected temperature is fluctuated. The standard deviation of errors in one frame caused was evaluated as much as 0.031 deg.C.

By applying the compensating algorithms for the first and the second errors, the standard deviation of errors in one frame could be reduced to 0.071 deg.C. At present, however, we have no effective method to correct the third error.

3. MUBEX/96 CAMPAIGN

MUBEX/96 was held from July 15th to August 12th, 1996. Table 2 shows the list of TIC operation during the campaign. TIC was usually operated around No. 6 buoy of MBAMMBS from one hour before and to one hour after the satellite overpass. The vessel was used to run along transect one mile away and across the buoy with speed one knot.

Table 2 The list of TIC Operation During the MUBEX'96 campaign.

	time		total	target
date	start	end	images	satellite
96/07/20	11:17:51	12:00:35	620	
	12:03:50	12:17:08	799	
	12:18:26	13:30:29	1045	NOAA-14
	13:30:33	15:24:46	1656	
96/07/21	12:22:20	14:03:31	1467	NOAA-14
96/07/22	12:31:12	13:57:45	1255	NOAA-14
	13:59:21	14:08:45	565	
	14:09:21	14:15:42	93	
96/07/24	18:03:13	18:31:51	416	NOAA-12
	20:29:29	22:35:10	1822	ERS-2
96/07/26	20:50:56	22:41:42	1606	ERS-1
96/07/27	1:19:28	2:22:33	915	NOAA-14
96/07/29	7:44:25	8:23:25	566	
	10:06:35	10:56:00	717	ERS-1
	11:35:32	11:52:17	1006	
	12:15:02	12:31:41	1000	
	20:25:25	22:29:51	1804	ERS-1
	23:47:42	23:58:01	620	
96/07/31	11:15:35	13:32:01	1978	NOAA-14
	13:37:52	14:07:52	1801	
96/08/01	9:22:05	11:00:47	1431	ERS-1
	11:58:25	13:01:14	911	NOAA-14
	17:32:04	18:49:51	1128	NOAA-12
96/08/02	8:38:31	8:55:10	1000	
	9:40:45	11:30:04	1585	ERS-2
	11:45:25	13:00:14	1085	NOAA-14
96/08/04	5:58:04	8:01:53	1795	NOAA-12
96/08/05	9:22:25	11:46:27	2088	ERS-2
	17:18:06	18:54:03	1261	NOAA-12
	20:36:04	22:00:08	1219	ERS-1
96/08/06	16:44:06	18:30:23	1541	NOAA-12
	20:34:52	22:00:39	1244	ERS-2
96/08/07	8:58:53	9:28:52	1800	
	9:38:05	11:00:09	1190	ERS-1
96/08/09	10:55:35	14:00:57	2687	NOAA-14
	20:35:45	21:46:13	1022	ERS-2
96/08/10	11:49:25	13:00:00	4236	NOAA-14

Figure 4 shows examples of TIC image. Depending upon weather and sea state conditions, the pattern of skin temperature distribution changes delicately. Images of A and B has rather homogenous temperature distribution, but in the images of C-H, patches of cold regions and warm regions are apparent. Wind may mix up the sea surface to provide homogeneous temperature distribution, but sometimes breaks sea skin to provide patch patterns of temperature distribution. In image of I, there appeared high temperature spots caused by sun-glint. Usually, the emissivity of thermal infrared of sea surface has been assumed as 1.0, but image of I suggests that the assumption is not always correct.

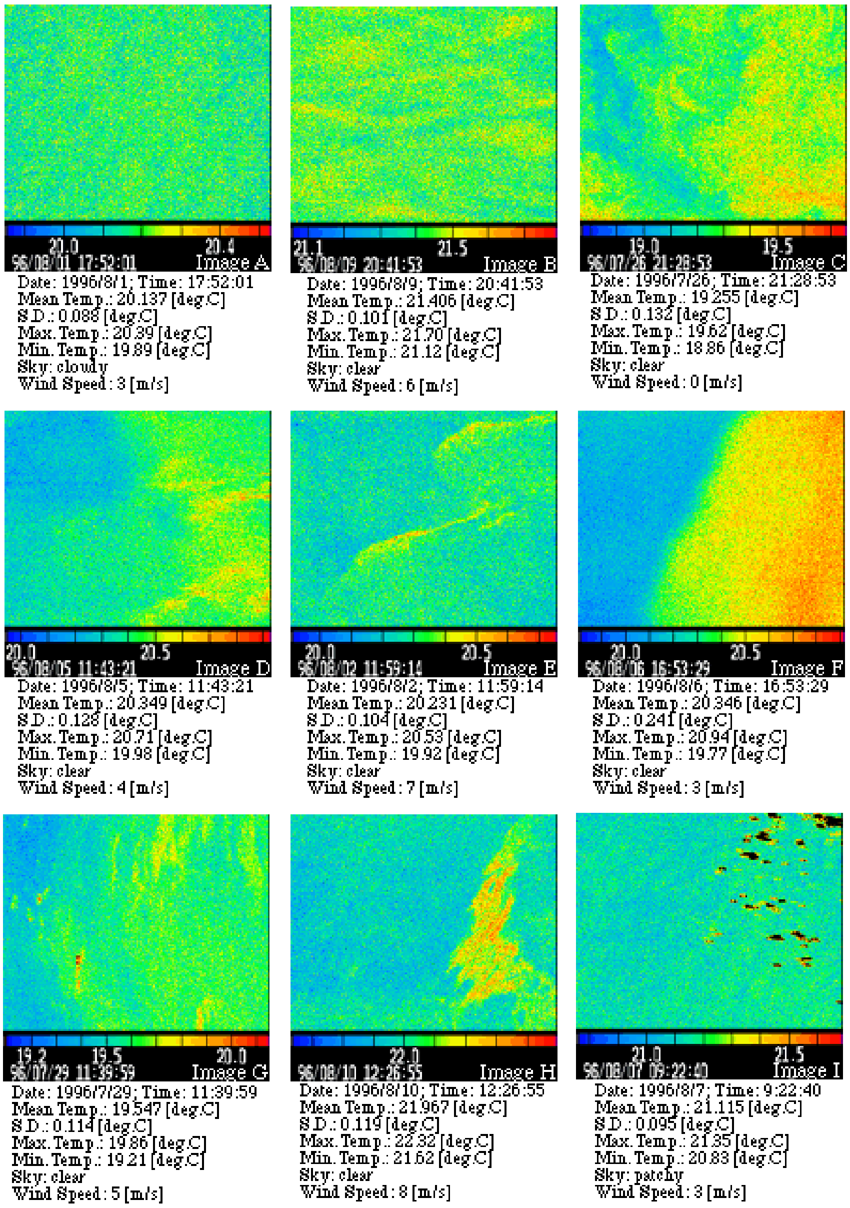


Figure 4 Examples of TIC images under various weather conditions.

Figure 5 shows the combined graphs of data observed from 09:20 to 11:40 (Japanese standard time) on August 5th. Solar radiation and wind speed were measured by M-Sta, water temperatures at -0 cm and -2 m were measured by M-SSO. Water temperature by TIC is calculated as the mean in one image frame. The water temperature difference between -0 cm and -2 m was 1 deg.C at 9:20, but it gradually decreases as wind speed gradually increased from morning to noon. After 11:00, the temperature at -2 m increased a little and the temperature difference almost disappeared. The data relevantly show the process breaking the stratified temperature layers by wind. Another interesting aspect is the difference between water temperature at -0 cm and the water temperature by TIC. Although both temperatures changed temporally, their difference was kept almost constant as 1.0 deg.C. This suggests to estimate the amount of skin effect, but in order to get more definite answer, we need more data under various weather conditions.

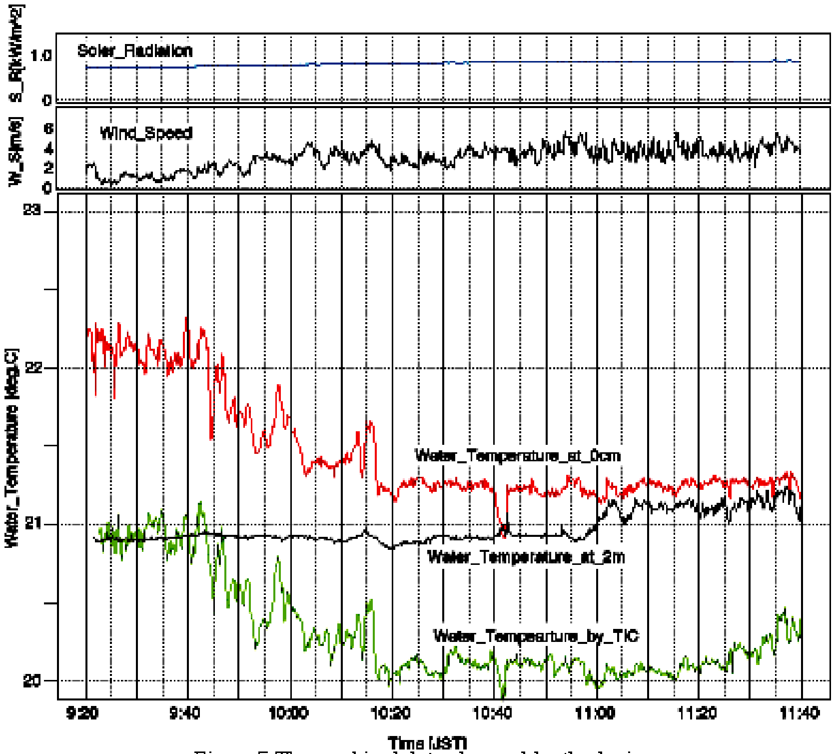


Figure 5 The combined data observed by the devices on the vessel from 09:20 to 11:40(JST) on August 5th.

4. CONCLUSION

Through MUBEX, we have established an observation system for validation of satellite SST and investigation of water temperature near sea surface. TIC data relevantly provides various aspects of spatial and temporal behaviors of sea skin temperature. MUBEX/97 will be held in the summer and we will get new data set. Because we have spent so much time to develop systems for data processing and correction algorithm, we are still in an early stage of data analysis. The MUBEX data will be expected to provide relevant aspects of air sea interaction of heat exchange at sea surface.

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