Journal of Oceanography
Vol. 48, pp. 345 to 351. 1992

Short Contribution

Accuracies of NOAA/NESDIS Sea Surface Temperature Estimation Technique in the Oceans around Japan

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(Received 21 October 1991; in revised form 6 March 1992; accepted 6 March 1992)

We have examined accuracies of nine nighttime National Oceanic and Atmospheric Administration/National Environmental Satellite, Data and Information Service (NOAA/NESDIS) equations for SST estimation using the Advanced Very High Resolution Radiometer (AVHRR)/NOAA-11 dataset produced by Sakaida and Kawamura (1992). Among the nine equations, the revised triple-window CPSST algorithm gives the smallest rms error, which is 0.38°C. The dual-window MCSST algorithm gives the largest rms error 0.56°C. Rms errors of the other algorithms are smaller than 0.5°C.

1. Introduction

Currently, sea surface temperatures (SSTs) are often retrieved from satellite observations by means of regression equation. Two types of regression equation have been examined for AVHRR/NOAA SSTs retrieval. The Multi-Channel SST (MCSST) algorithm is a linear regression equation (e.g., McClain *et al*., 1985) and the Cross Product SST (CPSST) algorithm is a non-linear regression equation (Walton, 1988). In these algorithms, two or three brightness temperatures observed by different wavelength bands in the infrared region are employed for the atmospheric correction.

The Advanced Very High Resolution Radiometer (AVHRR)/NOAA-11 has 5 channels and these channels are in the following wavelength ranges: 0.58–0.68 μm, 0.725–1.10 μm, 3.55–3.93 μm, 10.30–11.30 μm and 11.50–12.50 μm, hereafter, referred to as channels 1–5 respectively. Since three different brightness temperatures are provided in the case of AVHRR/NOAA-11, the variety of combination of brightness temperatures exists. "Split-window" technique uses brightness temperatures of channels 4 and 5 and "dual-window" technique uses brightness temperatures of channels 3 and 4. The technique using brightness temperatures of channels 3, 4 and 5 is called "triple-window" technique. For each of the three combinations, the MCSST and CPSST algorithms can be applied for SSTs retrieval. NOAA/NESDIS (1991) published eleven equations as shown in Table 1 and Table 4 (NOAA/NESDIS stands for National Oceanic and Atmospheric Administration/National Environmental Satellite, Data and Information Service). In this paper, we report on accuracies of nine NOAA/NESDIS SST estimation techniques using the nighttime dataset produced by Sakaida and Kawamura (1992, hereafter referred to as SK).

2. Data

The HRPT data of AVHRR/NOAA-11 consisting the dataset by SK were received by the Earth Observing Satellite Center (EOSC) of Tohoku University during November 1988 through

Table 1. NOAA/NESDIS equations for SST estimation using AVHRR/NOAA-11. The MCSST algorithms were published in September 27th, 1989 and the CPSST algorithm in March 2nd, 1990 (NOAA/NESDIS, 1991). T_3, T_4 and T_5 are AVHRR Channels 3, 4 and 5 respectively. ϕ denotes satellite zenith angle. Unit are °K.

(a)	Split-window	$MCSST = 1.052T_4 + 2.397089(T_4 - T_5) + 0.959766(T_4 - T_5)(\sec\phi - 1) - 1.316674$
		$CPSST = \dfrac{0.19817T_5 - 49.15}{0.20524T_5 - 0.17334T_4 - 6.10}(T_4 - T_5 + 1.47) + 0.96554T_5 + 0.96(T_4 - T_5)(\sec\phi - 1) + 6.02$
(b)	Dual-window	$MCSST = 1.03432T_4 + 1.347423(T_3 - T_4) + 0.953042(T_3 - T_4)(\sec\phi - 1) + 1.730466$
		$CPSST = \dfrac{0.17115T_4 - 54.64}{0.17334T_4 - 0.07747T_3 - 30.94}(T_3 - T_4 - 3.64) + 0.98737T_4 + 1.59(\sec\phi - 1) + 11.38$
(c)	Triple-window	$MCSST = 1.036027T_4 + 0.892857(T_3 - T_5) + 0.520056(T_3 - T_5)(\sec\phi - 1) + 0.61680805$
		$CPSST = \dfrac{0.16949T_4 - 54.11}{0.20524T_5 - 0.07747T_3 - 41.60}(T_3 - T_5 - 6.73) + 0.97778T_4 + 1.41(\sec\phi - 1) + 14.17$

Table 2. The distribution of the data.

Buoy No.	1988 NOV	DEC	1989 JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
21001							1	1	2	4		2	2	1	13
21002			2		2	1	2	2	2	5		3	1		20
21004		1	1							4	2	4	1	1	14
22001										2	1		1		4
Total		1	3		2	1	3	3	4	15	3	9	5	2	51

December 1989. As sea-truth SSTs were used the water temperatures measured at 1 m depth by Ocean Data Buoys operated by Japan Meteolorogical Agency. Production processes of the dataset were described in SK in detail.

Channel 3 data is available to use for SST estimation only in nighttime since channel 3 data are influenced by sunlight in daytime. Therefore, we use only nighttime dataset for comparing different types of technique. The total number of dataset is 51. For each buoy, the distribution of dataset for each month is shown in Table 2. The accuracy of split-window technique, which is available in daytime, has been examined by SK.

3. Results and Discussions

3.1 MCSST published September, 1989 and CPSST March, 1990

Figure 1 shows the difference between SST estimated by six equations and in-situ SST. Table 3 shows rms errors and biases of each SST estimation. According to Fig. 1, most of the differences between the satellite-derived SST and in-situ SST are distributing within a ±1°C range. All techniques examined here give rms errors smaller than 0.6°C. According to Table 3, the triple-window MCSST algorithm gives the smallest rms error, which is 0.43°C. The dual-window CPSST algorithm gives the next smallest rms error, 0.44°C. On the other hand, the dual-window MCSST algorithm gives the largest rms error, 0.56°C. The biases of CPSST algorithms

Table 3. The rms errors and biases of the satellite SSTs derived from equations as shown in Table 1. Unit are °C.

Method	MCSST rms	MCSST bias	CPSST rms	CPSST bias
(a)	0.48	−0.16	0.48	−0.22
(b)	0.56	−0.04	0.44	−0.14
(c)	0.43	−0.07	0.48	−0.27

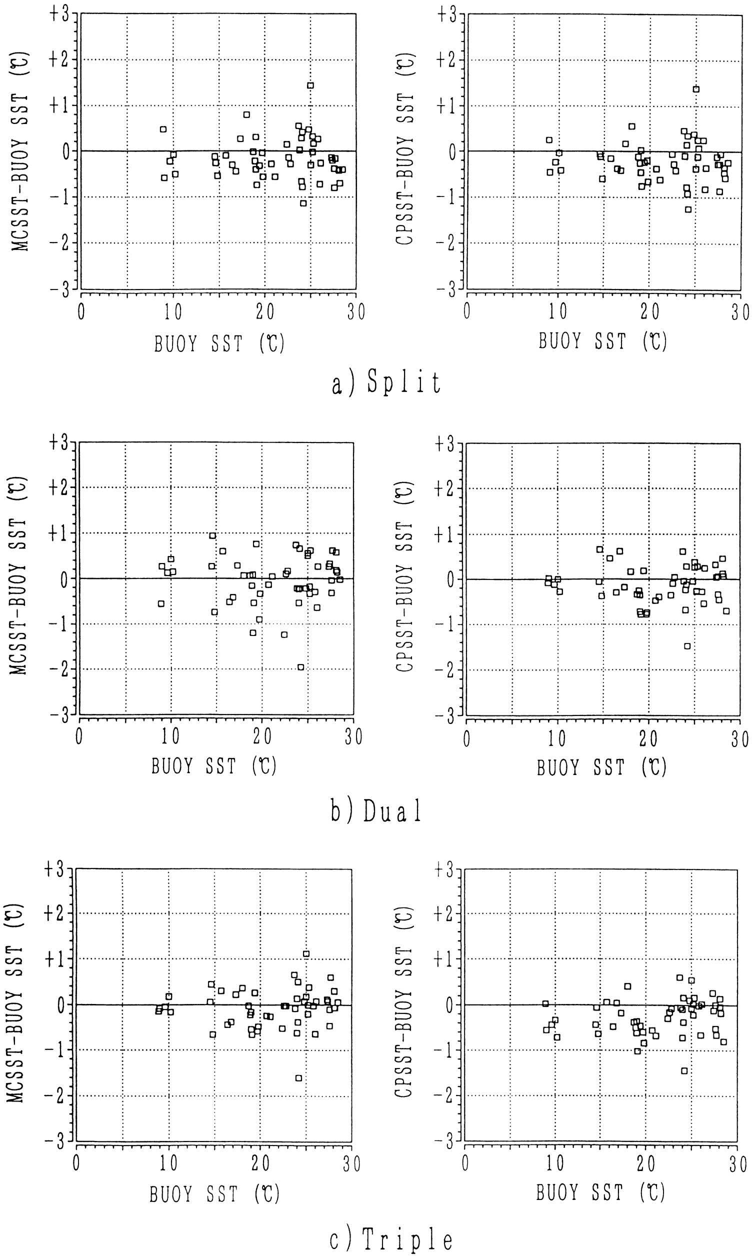

Fig. 1. The difference between satellite SSTs and buoy SSTs versus buoy SSTs. (a) split-window, (b) dual-window and (c) triple-window technique.

Table 4. Revised NOAA/NESDIS equations in April 10th, 1990 (NOAA/NESDIS, 1991). T_3, T_4 and T_5 are AVHRR Channels 3, 4 and 5 respectively. ϕ denotes satellite zenith angle. Unit are °K.

Daytime	
Split-window	$MCSST=1.0155T_4+2.50(T_4-T_5)+0.73(T_4-T_5)(\sec\phi-1)-4.84$
	$CPSST=\dfrac{0.19069T_5-49.16}{0.20524T_5-0.17334T_4-6.78}(T_4-T_5+0.789)+0.92912T_5+0.81(T_4-T_5)(\sec\phi-1)+18.97$
Nighttime	
(d) Split-window	$CPSST=\dfrac{0.19596T_5-48.61}{0.20524T_5-0.17334T_4-6.11}(T_4-T_5+1.46)+0.95476T_5+0.98(T_4-T_5)(\sec\phi-1)+9.31$
(e) Dual-window	$CPSST=\dfrac{0.17079T_4-58.47}{0.17334T_4-0.07747T_3-33.74}(T_3-T_4-6.44)+0.98530T_4+1.97(\sec\phi-1)+15.87$
(f) Triple-window	$CPSST=\dfrac{0.16835T_5-34.32}{0.20524T_5-0.07747T_4-20.01}(T_3-T_5+14.86)+0.97120T_5+1.87(\sec\phi-1)-3.44$

Table 5. Results of SST estimation by equations shown in Table 4. Unit are °C.

Method	CPSST	
	rms	bias
(d)	0.46	−0.14
(e)	0.41	−0.07
(f)	0.38	−0.12

is larger than those of MCSST algorithms for each of the three combinations of brightness temperatures.

The present study shows that rms errors of all techniques are smaller than 0.5°C except for the dual-window MCSST algorithm, whose rms error is 0.56°C. The previous studies (e.g., McClain *et al*., 1985; Walton, 1988) have shown rms errors about 0.6°C for each of six techniques. The reason for the smaller rms errors may be due to the limited area and period of the present study. The reason why the biases of CPSST is lower than these of MCSST is not clear at present, and needs further investigations.

3.2 CPSST published April, 1990

NOAA/NESDIS often revises SST estimation equations. Newer algorithms were published in April 18th, 1990. All revised equations are shown in Table 4. As shown in Table 4, NOAA/NESDIS mainly uses the CPSST algorithms rather than the MCSST algorithms. Results about daytime algorithms are not discussed here.

Table 5 shows rms errors and biases of each SST estimation. All results in Table 5 are better than the former. Especially, rms error of the triple-window CPSST algorithm is improved from 0.48 to 0.38°C. The new triple-window CPSST algorithm is better than the triple-window MCSST algorithm for our dataset. However, the new triple-window CPSST algorithm has negative bias as before. When the bias is corrected, we might get more accurate SSTs by the triple-window CPSST algorithm. It is suggested to investigate further the CPSST algorithms to evaluate a more accurate SST estimation in future.

Acknowledgements

We wish to thank the Oceanographical Division of the Marine Department and the Meteorological Research Institute of the Japan Meteorological Agency for providing us the data from the Ocean Data Buoys. This study is supported by a Grant-in-Aid for Scientific Research 01646010 from the Ministry of Education, Science and Culture, Japan, and is also supported as part of the cooperative research work between Tohoku University and Tohoku Electric Company.

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