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The Study on the Oceanic Surface Wind Retrieval using TRMM Microwave Imager

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TRMM TMI를 이용한 해상풍 추정에 관한 연구

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ABSTRACT

Ocean surface wind speed was estimated using TRMM (Tropical Rainfall Measurement Mission) TMI (TRMM Microwave/Imager) data. It is used the TRMM TMI brightness temperature and National Data Buoy Center's buoy winds speed dataset near North-America to estimate by the algorithm of the ocean surface wind speed retrieval over North America. Comparing with the buoy data by D-matrix equation, the result that RMSE, BIAS, and correlation coefficient are 2.19 ms^{-1}, 1.10 ms^{-1}, and 0.81, respectively. Therefore the estimated oceanic surface wind speed by TRMM TMI brightness temperature data show that available to ocean research over upper ocean.

KEYWORDS: Brightness Temperature, Ocean Surface Wind, Microwave Radiometer, Regression Equation

요 약

본 연구에서는 열대강우관측 위성(TRMM) 자료를 이용하여 해상풍을 예측하였고, TRMM TMI 휘도 온도와 북미 주변의 NDBC (National Data Buoy Centers) 부이 자료를 이용하여 해상풍을 추정하였다. 이 결과는 행렬방정식에 의한 부이와 비교하였는데 RMSE, BIAS 그리고 상관계수는 각각 2.19 ms^{-1}, 1.10 ms^{-1}, 그리고 0.81로 나타났으며, 이 결과는 앞으로 TRMM TMI를 이용한 해양 연구에 가능성을 보여주었다.

주요어: 휘도온도, 해상풍, 마이크로파 복사계, 회귀식

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INTRODUCTION

It is of great importance to obtain observational data with simultaneousness and repetitiveness in the studies of oceanic surface wind, which has been, however, very difficult. Observation by marine probes vessel hardly produces repetitive oceanic data whereas mooring buoys cannot cover broad areas(Konda et al., 1996). On the other hand, satellites guarantee both simultaneous and repetitive data since they are capable of periodical observation over broad areas(Ulaby et al., 1986; Shibata, 1992).

Microwaves from the ocean have close links to the structure of waves and the roughness of the ocean surface, which are directly determined by winds adjacent to the oceanic surface (Wentz, 1992). As a result, the surface wind speed can be driven from the microwaves data(Hollinger et al., 1990). Up to now SSM/I (Special Sensor Microwave/Imager) loaded in DMSP(Defense Meteorological Satellite Program) has been commonly used in the studies of oceanic surface wind speed (Yu et al., 1997; Bennartz, 1999). Recently, however, TMI(TRMM Microwave Imager) loaded in TRMM(Tropical Rainfall Measuring Mission), a satellite for joint project between the US and Japan, is being often used. TMI, composed of five channels(10.65 GHz, 19.35 GHz, 22.235 GHz, 37.0 GHz, 85.5 GHz), has horizontal resolution of 5 km(85.5 GHz) to 45 km(10.65 GHz), triple of SSM/I(65 km).

The purpose of this study is to retrieve oceanic surface wind speed from TRMM TMI data and to validate it by comparison with NDBC buoy data and NCEP/NCAR reanalysis data. This study will thus suggest the possible usefulness of TRMM TMI brightness temperature data in oceanic research.

DATA AND METHODS

1. Data

1) TRMM TMI satellite data and NCEP/NCAR reanalysis data

TRMM TMI comprises five channels which simultaneously observe microwaves emitted from the surface of the earth and the atmosphere. Four of TMI's channels(10.65GHz, 19.35GHz, 37.0GHz and 85.5GHz) provide horizontal and vertical polarization observation while 22.235GHz gives only vertical one. TMI antenna's caliber has scanning angle of 65 degree and swath width of 760km. The resolution of 10.65GHz, 19.35GHz, 22.235GHz and 37.0GHz are, respectively, 63×37km, 30 ×18 km, 27×18 km, 16×9 km, narrower than that of 85.5GHz(7×5 km).

This study is a result of observation on North American areas located between latitudes 15°N to 30°N and longitudes 70°W to 120°W. Mainly utilized data are TRMM TMI Brightness Temperature level 1B data from May through December, 1998. We verify estimated oceanic surface wind speed by comparing the data with the wind speed and direction from NCEP/NCAR reanalysis data. NCEP/NCAR has resolution of 2.5°×2.5°, the monthly average of which is used for the validation process.

2) Buoy data

In order to validate the oceanic surface wind speed derived from TMI data, it is compared with the buoy data of NOAA NDBC(National Data Buoy Center) during the same period. Buoy data, with the error range of ±0.5 ms^{-1}

vis-a-vis winds weaker than 10 ms-1 and ±2 ms^{-1} vis-a-vis those stronger than 10 ms^{-1}, has hourly average of 8.5 minutes. Buoy drifting more than 100 km away from the land is chosen to avoid the data contamination of oceanic brightness temperature(Table 1). To increase the validity of verification, corrected data of buoy winds and D-matrix are taken only when TMI observation took place within 25km from the location of the buoy and if TMI passed the area within 30 minutes since the buoy observed the wind speed. Since the speed sensor of NDBC buoy records the wind speed at the altitude of between 3m to 10m, to compare with TMI algorithm result, it is converted to a data equivalent to the altitude of 19.5m using equation (1) (Liu and Blanc, 1984).

$$Wind\ speed\ (M_2) = M_1 \times \frac{\ln(z_2/z_0)}{\ln(z_1/z_0)} \qquad (1)$$

Wind speed(M_2) is defined to be zero at the ground(more precisely, at a height equal to the aerodynamic roughness length). Speed increases roughly logarithmically with height, but the shape of wind profile depends on the surface roughness. Here, M_1 is wind speed of buoy, z_2 and z_1 are the altitude of 19.5m and wind sensor height of NDBC buoy, z_0(=0.002m) is roughness length at the sea surface(Stull, 1995).

2. Method

It is by applying two data, TMI brightness temperature and buoy oceanic surface wind data identical to TRMM TMI observation on temporal and spatial basis, that we come up with oceanic surface wind speed algorithm. The algorithm used is empirical equation (2),

$$U = C_0 + C_1 T_B(19H) + C_2 T_B(22V) + C_3 T_B(37V) + C_4 T_B(37H) \qquad (2)$$

DMSP wind speed retrieval D-matrix (Goodberlet et al., 1989). The U (Oceanic surface wind speed) here is converted to a standard data equivalent to the altitude of 19.5m. The empirical equation (2) includes TB, which represents the brightness temperature of the frequency/polarization composition. H, V, and C respectively stand for horizontal polarization, vertical polarization and D-matrix. This study adopts the empirical

TABLE 1. Description of NDBC buoys

Buoy	Number	Latitude (°N)	Longitude (°E)	Height(m)
NDBC	41001	34.68	287.42	6.0
	42001	25.92	270.35	10.0
	42002	25.88	266.43	10.0
	42036	28.50	275.50	3.0
	44004	38.45	289.32	6.0
	44011	41.08	293.42	6.0
	46002	42.52	229.75	6.0
	46003	51.85	204.10	6.0
	51002	17.18	202.18	6.0

* Height is for the wind sensor

TABLE 2. Coefficient and relative performance of the best global multichannel D-matrix algorithms

Coefficient		19*V*	19*H*	22*V*	37*V*	37*H*	*r*
C_0	48.1536	-	-0.1017	-0.2425	0.3127	-0.1816	0.81
C_1	51.8556	-0.4115	0.1836	-	0.1728	-0.1735	0.75
C_2	45.8727	-0.5493	0.3549	0.0085	-	0.0106	0.56
C_3	54.8144	-0.3874	0.2367	-0.2582	0.1740	-	0.58

* r is correlation coefficient

equation (2). As specified in Table 2, the coefficient with the utmost correlation is applied to the retrieval of oceanic surface wind speed.

RESULTS

We have retrieved oceanic surface wind speed in the vicinity of the North American continent by processing DMSP wind speed retrieval D-matrix algorithm to TRMM TMI brightness temperature data. Figure 1 is a scatter plot showing the comparison between the oceanic surface wind speed from buoy data and the one retrieved from TRMM TMI data. The comparison of July and November data shows correlation coefficient of 0.81, RMSE is 2.19 ms^{-1}, and the bias is 1.10 ms^{-1} (refer to Table 3). The correlation coefficient is slightly smaller than the value(0.84) by Jang et al.(1997) using SSM/I retrieval method while the bias has decreased by 0.42 ms^{-1}. Figure 2 also indicates that wind speed stronger than 10ms^{-1} tends to cause somewhat overestimated result. Figure 2 illustrates a distribution of wind speed in May, July and November derived from TRMM TMI data. According to Figure 2, November has stronger wind speed than May and July and the highest speed derived during these periods is approximately 13 ms^{-1}. Overall result of this study has similar trends shown in the previous studies while we admit that our study leads to somewhat overestimated result.

Figure 3 shows that wind speed estimated from TRMM TMI data is overestimated in comparison with NCEP/NCAR reanalysis data but still has trends similar to Figure 2.

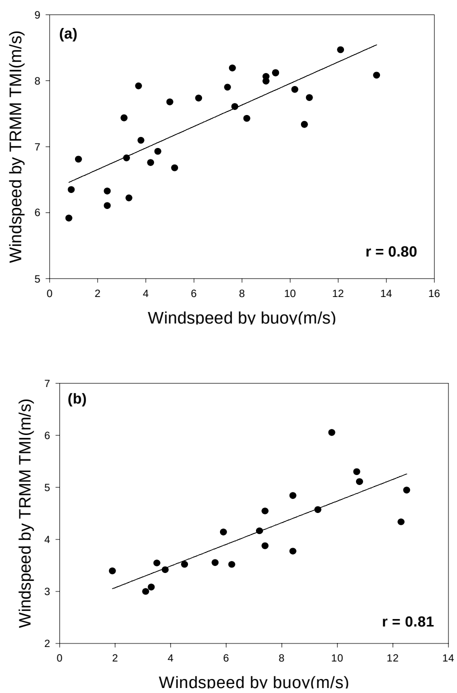

FIGURE 1. Comparison of the surface wind speed derived from TMI data with that from NDBC buoys, (a) July and (b) November, 1998

TABLE 3. Statistical comparison of the TRMM TMI and NDBC buoy wind speed

Name of source data	Mean (ms^{-1})	RMSE	BIAS	*r*
NDBC buoy	6.24	2.19	1.10	0.81
TRMM TMI	7.34			

∗ r is the correlation coefficient

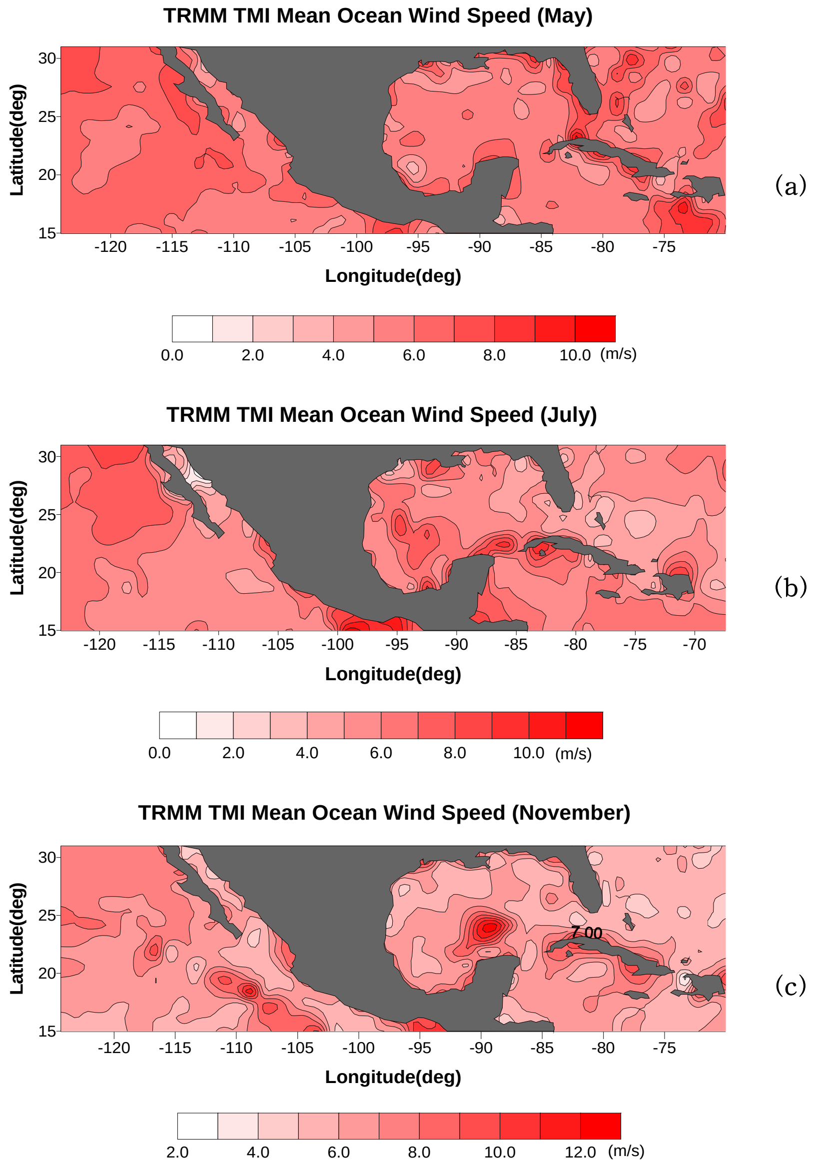

FIGURE 2. Distribution of oceanic surface wind speed in the study area estimated from TRMM TMI data, (a) May, (b) July and (c) November, 1998

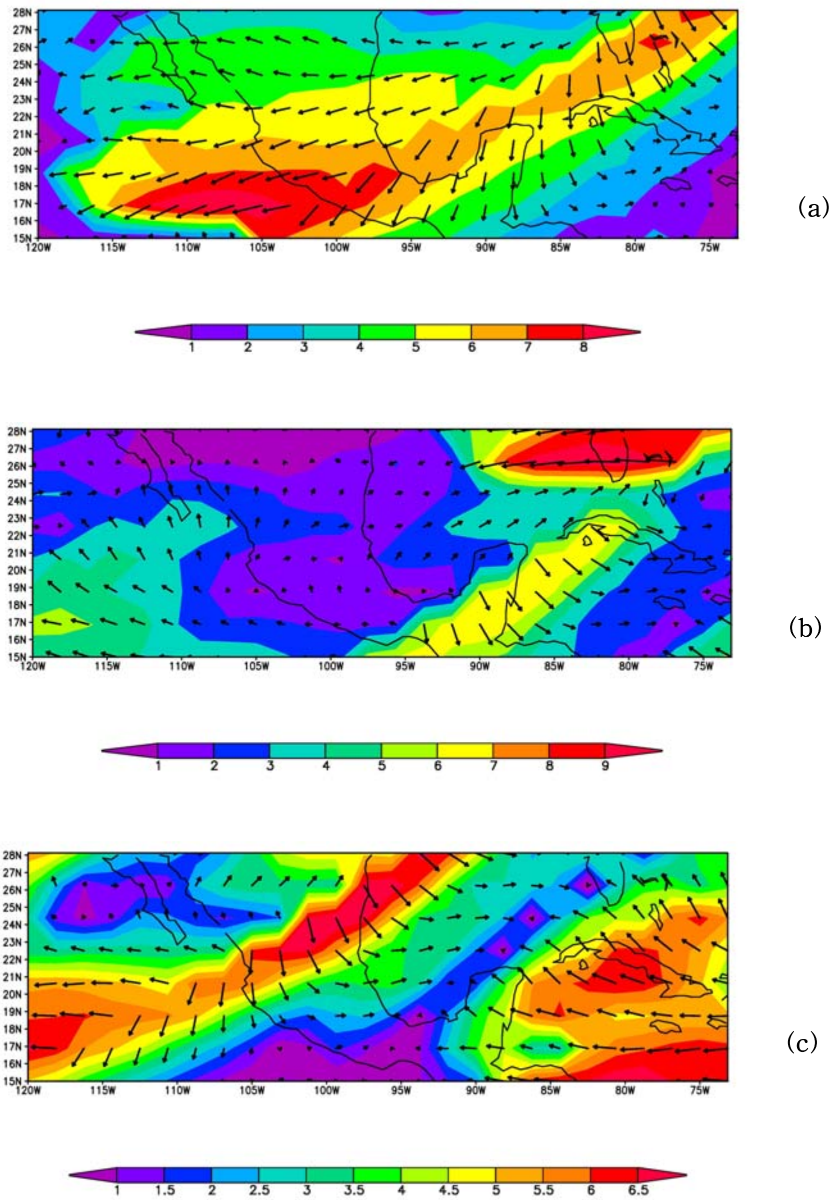

FIGURE 3. Averaged wind speed and direction from NCEP/NCAR reanalysis data, (a) May, (b) July and (c) November, 1998

CONCLUSIONS

For the purpose of estimating the oceanic surface wind speed around North American continent, a wind speed retrieval algorithm has been applied to TMI brightness temperature data and the observational data of the buoy in order to avoid influenced by the continents.

The coefficient with the highest correlation level has been selected and applied to the data, which has resulted in significantly high correlation of 0.80 and 0.81 in July and November, respectively. Average wind speed in May, July and November is also similar to the result of preceding studies as well as to NCEP/NCAR reanalysis data. Nevertheless, this study has taken only data over 8 months from May to December 1998 thus failed to take seasonal or climate change into consideration.

Though it is admitted that this study leads to a slightly overestimated result compared to the wind speed from buoy data and NCEP/NCAR reanalysis data, it has demonstrated the positive prospects of oceanic studies using TRMM TMI data. Thus, more studies should follow based on long-term observational data. KAGIS

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