

A Statistical Method to Get Surface Level Air-Temperature from Satellite Observations of Precipitable Water

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Ten-day mean surface level air-temperature from SSMI precipitable water (SSMI- T_a) has been derived and compared with the temperature from two ocean data buoys (Buoy- T_a) of Japan Meteorological Agency (JMA) for a period of six months (July–December, 1988). Statistical relations between air-temperature and mixing ratio, using data from ocean data buoys are used to derive air-temperature from mixing ratio, obtained from SSMI precipitable water. For getting the mixing ratio from precipitable water, regional mixing ratio-precipitable water relations have been used, instead of global relation proposed by Liu (1986). The rms errors (standard deviation of the difference between SSMI- T_a and Buoy- T_a) for two buoy locations are found to be 1.15 and 1.12°C, respectively. Surface level temperature for the two buoy locations are also derived using direct regression relation between Buoy- T_a and precipitable water. The rms errors of the SSMI- T_a , in this case are found to be reduced to 1.0°C.

1. Introduction

Satellite derived surface-level meteorological parameters are considered to be a better alternative to sparse ship observations for getting the estimates of heat flux across the air-sea boundary (Miller, 1981; Liu, 1988). Bulk method has widely been used for this purpose and the parameters required are: sea surface temperature, and wind speed, air-temperature and specific humidity within the first 50 meters of the air-sea boundary layer (Friehe and Schmitt, 1976; Liu *et al.*, 1979). Sea surface temperature derived from NOAA-AVHRR infrared channels, using MCSST/CPSSST algorithms, has an attainable accuracy of $\pm 0.5^\circ\text{C}$ (McClain *et al.*, 1985; Walton, 1988; Sakaida and Kawamura, 1992). The operational U.S. DMSP-SSMI provide the surface level wind speed and integrated column water vapor (precipitable water) within an accuracy comparable to in situ observations (Wentz *et al.*, 1986; Schlüssel and Emery, 1990; Schlüssel and Luthard, 1991). Liu (1986) proposed a global statistical relation between monthly mean precipitable water (W) and surface level humidity (Q) and he could delinilate the 1982–83 ENSO from the moisture and latent heat variabilities, by using the value of Q derived by this statistical relation.

However, in getting the sensible heat estimates by using satellite observed parameters, the availability of surface level air-temperature (T_a) within a reasonable accuracy have remained to be a major constraint. Though there are some satellite sensors (e.g. TOVS, Tiros-N Operational Vertical Sounders) to get the atmospheric temperature sounding, their vertical resolution is not adequate to provide T_a . In this study, we propose a statistical method to get ten-day mean T_a from satellite observations of W .

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2. Data and Methodology

Meteorological observations from two moored buoys (B21004; 135°E and 29°N, and B22001; 126°E and 28°N) of Japan Meteorological Agency for a period of six months (from July to December, 1988) are used in conjunction with SSMI-W within 150 km of distance from the

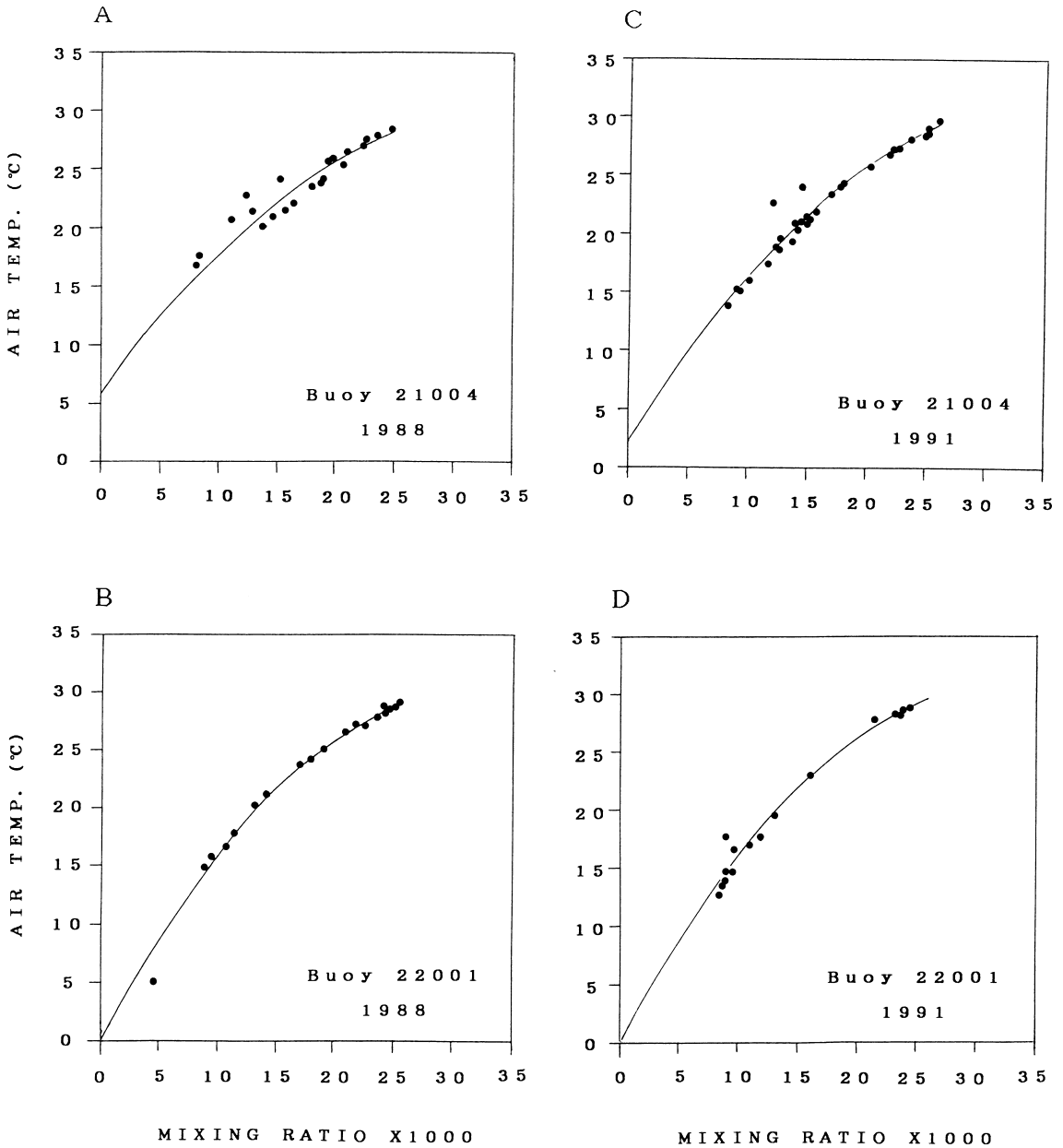


Fig. 1. (A): Regression relation between surface level air-temperature T_a and mixing ratio (multiplied by 1000) using data from ocean data buoy 21004 for the year 1988. (B), (C) and (D): Same as Fig. 1A except for buoy 22001 (1988), buoy 21004 (1991) and buoy 22001 (1991), respectively.

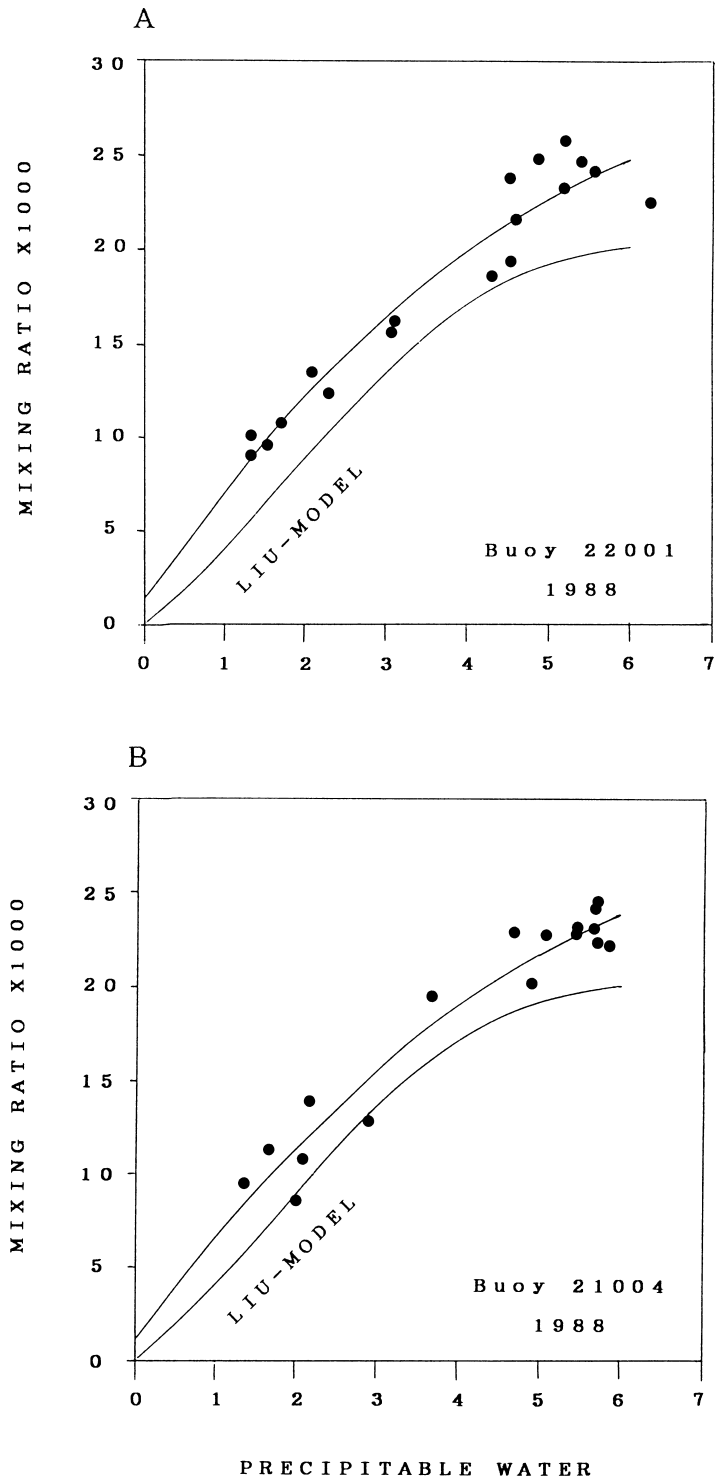


Fig. 2. Q - W relation at the locations of buoys 22001 and 21004, respectively, for the year 1988.

buoy positions and a time lag of one hour thirty minutes of satellite pass. In order to get the best regressable derived-surface-level parameter (such as water vapor, mixing ratio, relative humidity) with T_a , the correlation coefficients of these derived parameters with T_a have been worked out using buoy observations. Consistency of these correlations and trends for different year is also worked out using the 1991 buoy observations. The ten day mean regression relation between T_a and Q for two buoys and for two different years are given in Figs. 1A, 1B, 1C and 1D. For both the buoys and for both the years the Q is found to be well correlated with T_a , with a unique nonlinear trend.

This T_a - Q relation, from buoy observations is then used to get T_a from the Q , derived from SSMI- W . In order to see the validity of Liu's fifth order polynomial equation, for getting Q from 10 day mean W , we plotted 10 day mean Q (buoy) versus 10 day mean SSMI- W . Figures 2A and 2B give these regression relations for the year 1988 (from July to December) for buoys 22001 and 21004 respectively. Liu's model underestimated the ten day mean Q , consistently and coherently in both the cases. So, for this study, we use the mean of the quadratic regression constants of the two cases, shown in Figs. 2A and 2B to derive the Q from SSMI- W .

3. Results and Discussion

Statistically derived T_a from SSMI- W for the two buoy locations are given in Figs. 3A and 3B (for buoy 22001 and 21004, respectively). The dashed line (- - -) represents the ten day mean buoy T_a and the full line (—) represents the T_a derived from SSMI- W , hereinafter referred to as SSMI- T_a . The SSMI- T_a closely follows the buoy- T_a for all the 6 months in both of the buoy locations. The rms error in the SSMI- T_a is 1.15 and 1.12°C for buoy No. 22001 and 21004 respectively. rms errors will definitely be lesser than the present values, if SSMI- T_a is derived using respective W_a - Q relations for each buoy, instead of taking mean regression constants. This accuracy of SSMI- T_a (about 1°C, compared to buoy observation) is quite appealing for the computation of sensible heat flux using bulk method.

Since the accuracy of SSMI- T_a depends on the accuracy of Q derived from W , the regional and temporal dependance of Q on W has to be considered. The global relation between monthly mean Q and W , proposed by Liu (1986) was further validated by Hsu and Blanchard (1989) and they reported that the W - Q relation exists well not only for monthly period but for instantaneous soundings. The validity of Q - W relation for time scale varying from one to several days has been studied by Simonot and Gautier (1989), Eymard *et al.* (1989). All these studies indicate that there exists a dependance of Q on W and the degree of dependance varies with temporal scales. Liu *et al.* (1991) studied the reliability of Q - W relation for varying time scales (from one day to one month) using Empirical Orthogonal Function (EOF) and observed that the optimal time scales for the application of Q - W relation are periods greater than 10 days. In the two cases presented here, the regional Q - W relation differs from global relation in two aspects. Firstly, the global relation underestimates Q for the present area and secondly the sharp deflection in the higher W regions in the global relation is found to be weaker in the regional relation. The global relation represents data from different ocean regimes (from lower to higher latitudes) and is characterised with a wide range of values. This wide range of W and the long time interval in averaging (one month) may be the reason for underestimation of Q by global relation. Regarding the second difference, Liu (1986) argued that the deflection in the global Q - W relation for higher W values is due to the precipitable water data from equatorial region, where due to deep convection the water vapor trapped in the lower layer is uplifted to larger depths to alter the general Q - W relation. Depending on the regional air-masses there will be regional shifting in the global Q - W relation

proposed by Liu (1986). Therefore, for better accuracies in the SSMI- T_a , it is reasonable to use regional Q - W relations rather than global one.

Our results show that T_a is well correlated with the Q and Q is dependent on W . So, explicitly, there exists a relation between T_a and W . We worked out this direct relation between T_a and W and the relations are shown in Figs. 4A and 4B. Figures 5A and 5B give the temperature derived from SSMI precipitable water using this direct regression relation between T_a and W . Compared

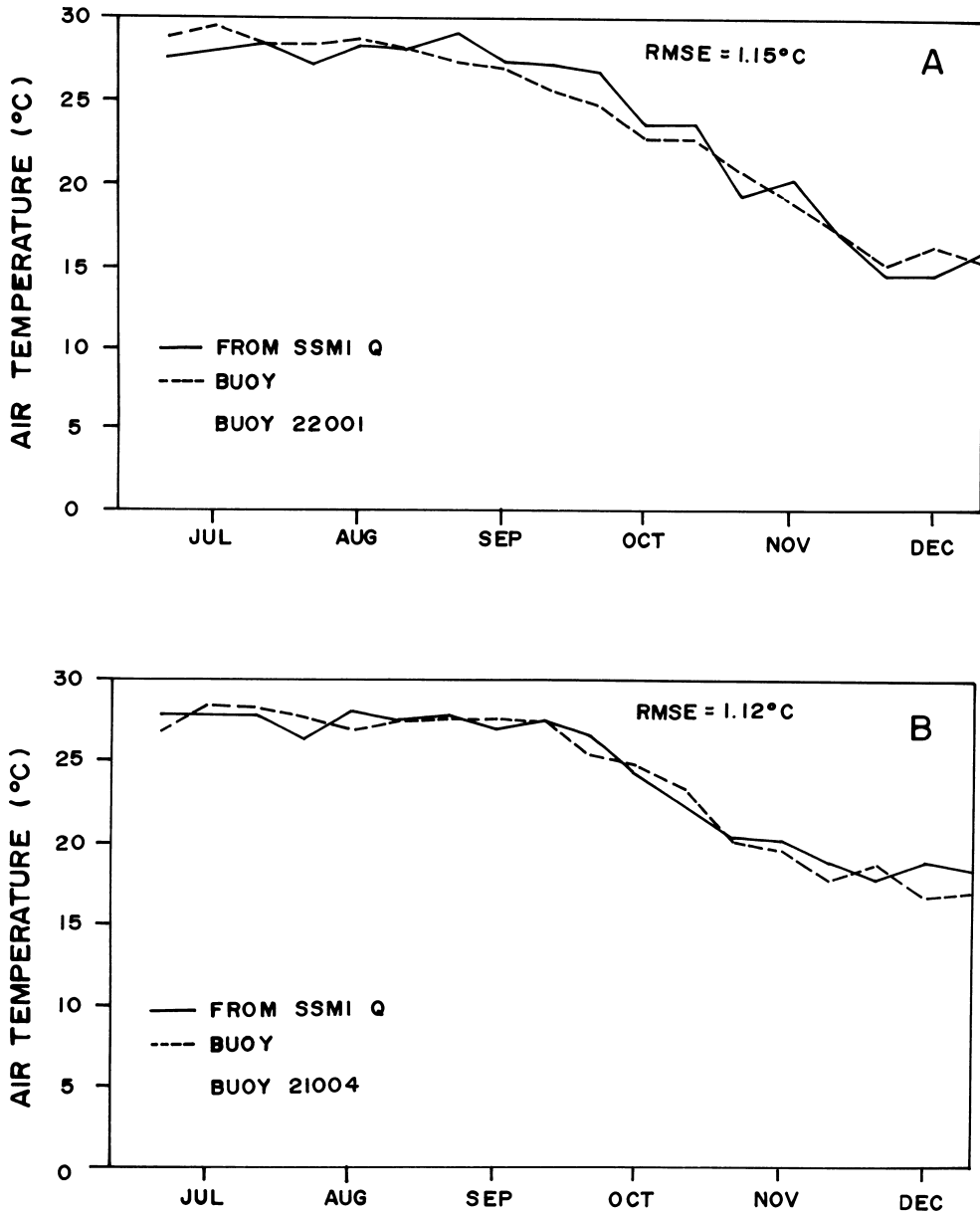


Fig. 3. Statistically derived surface level air-temperature from Q , obtained by using the regional Q - W relations shown in Figs. 2A and 2B, respectively.

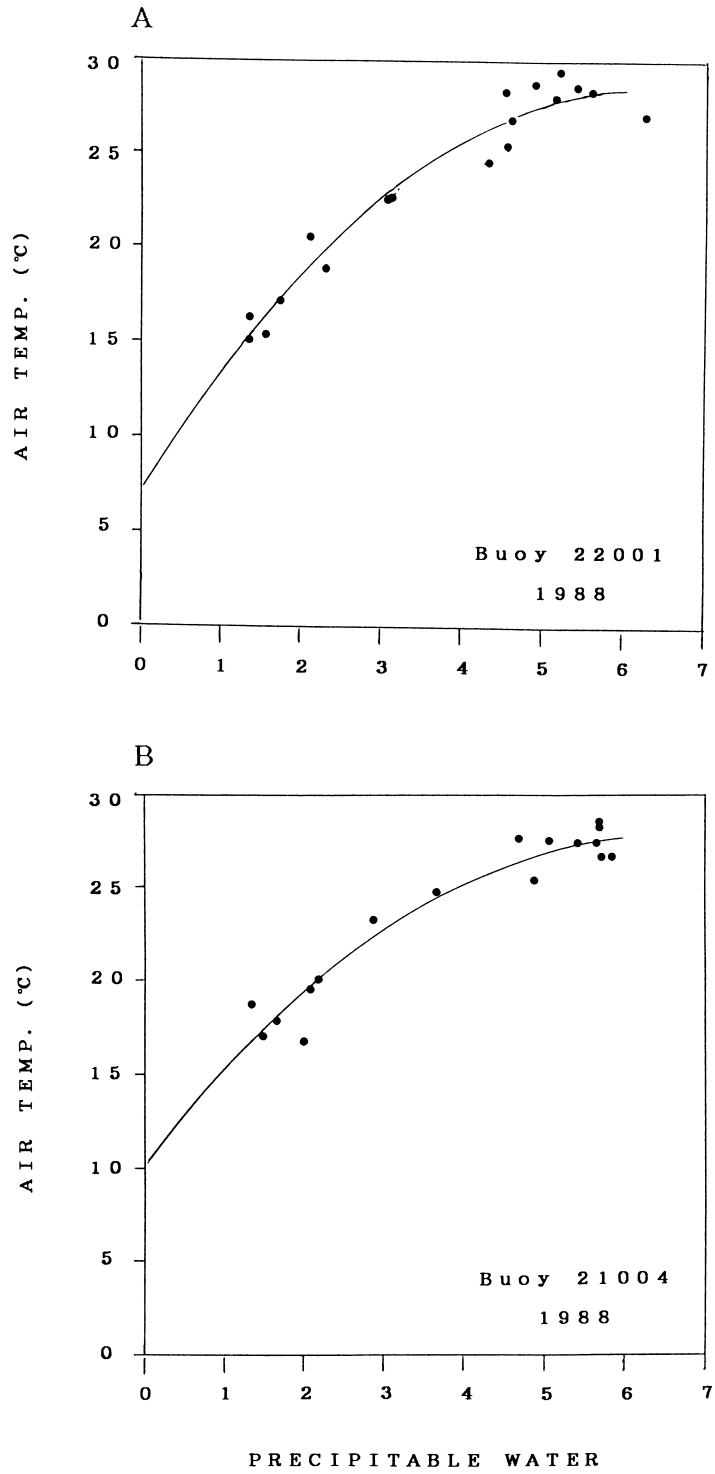


Fig. 4. T_a - W relations for buoy 22001 and 21004, respectively.

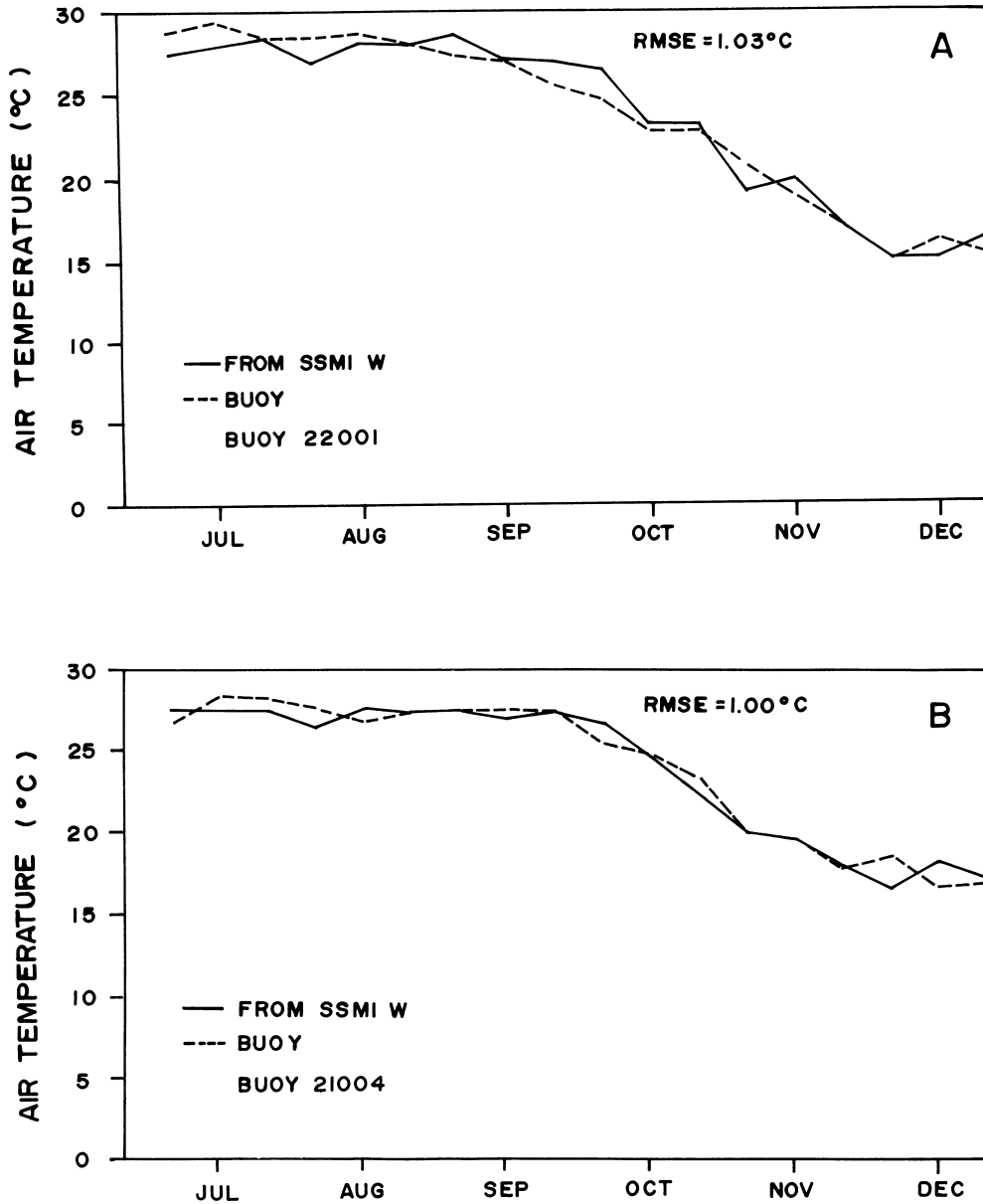


Fig. 5. Statistically derived surface level air-temperature using direct T_a - W regression relations shown in Figs. 4A and 4B, respectively.

to Figs. 3A and 3B for all the six months, there is no much marked deviation in the SSMI- T_a . The rms errors obtained in this case are 1.00 and 1.03°C, about ten percent lesser than the rms errors, involved in the indirect regression between T_a and W . For climatological studies, using monthly means, the rms error is likely to be lesser than 1°C, facilitating the estimation of sensible heat flux within a reasonable accuracy.

4. Concluding Remarks

The statistical method presented in this study can provide synoptic surface level air temperature with an accuracy of $\pm 1.0^{\circ}\text{C}$, compared to in situ observations. Since satellite sensors have not yet succeeded in the direct measurement of surface level temperature, this method can be used as an option. Though the satellite derived air temperature nearly follows buoy temperature, throughout the six months period (presented here) and for both the buoy locations, the applicability of this method has to be validated further, using SSM/I precipitable water and buoy observations for a longer period and covering different ocean regimes.

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