Sea Surface Emission Temperatures from Defense Meteorological Satellite

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1. Introduction

Several comprehensive studies (Church and Twitchell, 1972; Platt, 1972; Smith and Rao, 1972) have been completed comparing sea surface temperatures with airborne radiometric measurements. A recent study (La Violette *et al.*, 1975) examines the use of APT satellite infrared data from NOAA 1, NOAA 2 and Nimbus 3 in oceanographic surveys. Here, sea surface emission temperatures are derived from Defense Meteorological Satellite Program (DMSP) infrared (8–13 μm) radiance imagery obtained by DMSP Site 8 at the Cape Canaveral Air Force Station, Florida. The derived sea surface temperatures are ~9°C colder than the sea surface temperatures measured by the survey ship. The data sample consists of 31 pieces of information taken in the vicinity of 27¾°N, 80¼°W off the east coast of Florida. The results presented here supplement the findings of the studies mentioned above.

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2. Discussion

The DMSP sea surface IR radiance imagery was obtained by Site 8 at the Cape Canaveral Forecast

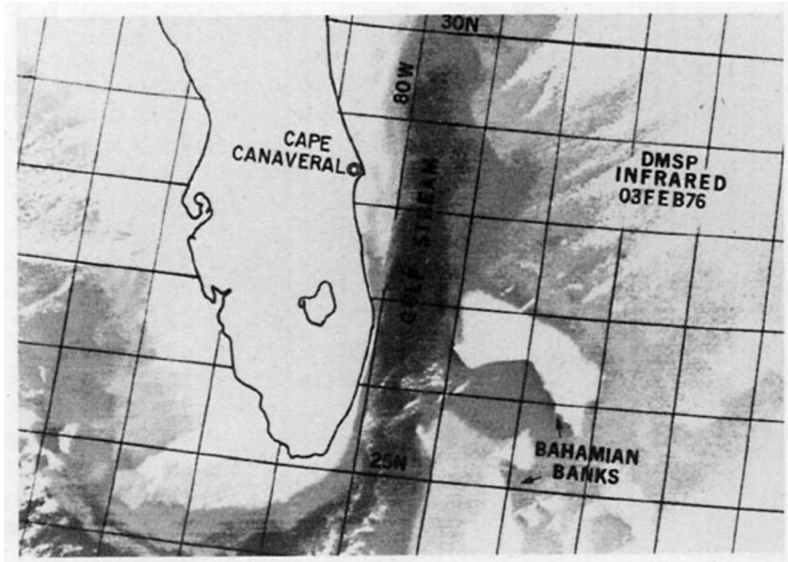

FIG. 1. DMSP infrared imagery from 3 Feb. 1976 using thresholding display mode. The four gray shades depict distinct temperature ranges with white corresponding to emission temperatures less than 282 K, light gray between 282–284 K, dark gray between 284–286 K and black denoting temperatures greater than 286 K.

Facility, Detachment 11, 2 Weather Squadron, Air Weather Service, USAF. Radiance energy is converted to sea surface temperatures by converting voltage levels to an analog signal and processing the resulting data onto a 7.5-inch photographic transparency via a cathode ray tube. The data display consists of from 2 to 64 gray shades depending on the process used and the temperature range desired. The most common settings for obtaining emission temperatures are four gray shades easily identifiable with the naked eye depicting four distinct temperature values. Thus the desired temperatures are mechanically displayed on the transparency which can be gridded for real-time analysis. The imagery is processed on the "Block V" processor, using the thresholding mode. With temperature settings of 282, 284 and 286 K, an example of this DMSP threshold data is shown in Fig. 1.

The "ground truth" sea surface temperature data was obtained from the oceanography department at the Florida Institute of Technology, Melbourne. The temperatures were measured by the "surface bucket temperature technique" with an accuracy of $\pm 0.1°C$.

The DMSP transparency from which Fig. 1 is taken was gridded geographically using a standard grid and accuracy is reliable to $\pm 0.1°$.

The DMSP WHR sensor has a resolution of 0.62 km ($\frac{1}{3}$ n mi) ($\sim 0.005°$ at 30°N); thus the data display is within an acceptable tolerance with the ground truth data, which was measured at $\sim 0.002°$ intervals.

3. Results

A series of comparisons have been run by the authors to compare the DMSP infrared 4.0 km resolution (2 n mi) and very high resolution infrared (WHR) sensors 0.62 km resolution. The WHR sensor will give temperature reading approximately 2°C cooler than the IR (*Spar*, January–April, Cape Canaveral AFS). Using this information along with the findings of Dickinson *et al.* (1974), we would expect the WHR temperature difference to be near 9°C at the location of the ground truth data.

Table 1 shows the results of the comparisons. The results support previous findings, i.e., radiometric values are colder and the differences between actual sea surface temperatures and radiometric emission temperatures are very nearly 9°C.

It should be mentioned that all of the data were carefully selected to insure that no cloud cover was present above the ocean to contaminate emission temperatures recorded by the infrared radiometers. The cooler emission temperatures obtained in this study were expected since atmospheric aerosols and differing path lengths, depending on the nadir angles of the satellite, contribute to colder emission temperatures. Atmospheric aerosols contributing to this negative bias could be haze, dust or ice crystals.

4. Correlation between DMSP IR emission temperature (ET) and actual sea surface temperature (SST)

To determine the relation between the two variables, first-, second- and third-order polynomials were fitted to the data. The third-order polynomial was deleted by inspection. To test the linearity of the data, a significance level of a quadratic fit over a linear fit was computed. The significance level of a quadratic term when sea surface temperature is fitted to the IR emission

TABLE 1. Data taken 3 February 1976 cruise SH76-07 Florida Institute of Technology, Melbourne.

Latitude	Longitude	Bucket (SST) sea surface temperature (°C)	DMSP (ET) emission temperature (°C)	SST−ET (°C)
27°28.5′N	80°16.2′W	19.7	11.0	8.7
27°28.4′N	80°14.3′W	20.8	11.0	9.8
27°28.3′N	80°12.8′W	21.3	11.0	10.3
27°28.1′N	80°11.8′W	21.5	12.0	9.5
27°28.2′N	80°10.8′W	21.4	12.0	9.4
27°28.2′N	80°09.5′W	21.4	12.0	9.4
27°28.2′N	80°08.5′W	20.8	12.0	8.8
27°28.3′N	80°07.3′W	20.4	11.0	9.4
27°28.3′N	80°05.9′W	20.6	11.0	9.6
27°28.6′N	80°05.0′W	20.5	10.0	10.5
27°28.8′N	80°03.7′W	20.6	11.0	9.6
27°29.1′N	80°02.7′W	21.3	12.0	9.3
27°29.5′N	80°01.7′W	22.0	12.0	10.0
27°29.8′N	80°00.5′W	22.6	13.0	9.6
27°30.4′N	79°59.5′W	22.9	13.0	9.9
27°31.0′N	79°58.5′W	22.3	13.0	9.3
27°31.3′N	79°57.8′W	21.6	13.0	8.6
27°31.3′N	79°57.6′W	21.2	13.0	8.2
27°31.3′N	79°57.6′W	20.4	12.0	8.4
27°31.7′N	80°08.5′W	20.8	12.0	8.8
27°31.5′N	80°08.9′W	21.0	12.0	9.0
27°31.4′N	80°09.7′W	21.0	12.0	9.0
27°31.4′N	80°09.8′W	21.4	12.0	9.4
27°31.2′N	80°10.5′W	21.5	12.0	9.5
27°31.1′N	80°11.4′W	21.6	12.0	9.6
27°31.1′N	80°12.8′W	21.4	12.0	9.4
27°31.0′N	80°13.8′W	20.8	12.0	8.8
27°30.9′N	80°14.8′W	20.5	12.0	8.5
27°30.9′N	80°16.0′W	20.2	11.0	9.2
27°30.8′N	80°17.2′W	19.8	11.0	8.8
27°30.8′N	80°17.6′W	19.9	11.0	8.9

temperature was 0.0552; therefore, a linear regression will not provide a good fit for the data. [Note: small values of the significance level (e.g., <0.05) indicate a lack of linearity.]

Thus the analysis of this data set was limited to computation of the mean temperature difference and standard deviation because of the limited size of the data sample, and the recurrence of identical temperature values for the DMSP sensor (three values), which made linear regression techniques unreliable. The mean temperature difference, $\Delta T=$ (SST−ET) was found to be 9.26°C with a maximum ΔT of 10.5°C and a minimum of 8.2°C. The standard deviation for the sample was computed to be 0.53°C.

5. Recommendations

The authors have made numerous comparisons with synoptic reporting stations and available ship and buoy reports. These comparisons give the notion of a direct temperature correction a great deal of credibility. The effects of atmospheric aerosols and other contaminants appear to be at a tolerance level, in cloud-free areas, which permits the use of a direct correction factor to the DMSP data with an accuracy of ± 1°C.

The calibration of the DMSP IR sensors for use in determining surface temperatures is not only feasible but practical. Comparison to conventional temperature mapping techniques currently in use bears this out. We recommend a large-scale gathering of ground truth data on a broader range of temperatures and geographical locations in order to further verify this premise.

Acquisition of oceanic thermal emission data by meteorological satellites with various instrument calibration errors (signatures) can provide global sea surface temperature measurements, provided cloud cover is scrutinized very closely. Since it would be impossible to cover the earth's water surfaces with buoys, satellite infrared imagery is the only solution for mapping these all-important surface temperatures. Environmentalists, oceanographers, as well as the fishing industries of the world, will depend on accurate satellite infrared imagery. However, the calibration problems of most satellite IR radiometers discourage oceanographers and meteorologists from using the ET data. The authors believe that the only solution to this dilemma is to standardize radiometric calibration curves and develop infrared signatures for ocean areas.

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