VALIDATION OF COASTAL SEA AND LAKE SURFACE TEMPERATURE MEASUREMENTS DERIVED FROM NOAA/AVHRR DATA

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ABSTRACT

An interactive validation monitoring system is being used at NOAA National Environmental Satellite, Data and Information Service (NESDIS) to validate the sea surface temperature (SST) derived from the NOAA 12 and NOAA 14 polar orbiting satellite AVHRR sensors for the NOAA CoastWatch program. In 1997, we validated the SST in the coastal regions of the Gulf of Mexico (GM), Southeast US (SE) and Northeast US (NE) and the lake surface temperature in the Great Lakes (GL) every other month. The *in situ* temperatures measured by twenty-five NOAA moored buoys are used as ground truth. The non-linear algorithm (NLSST) is used for all AVHRR SST estimation except during the day in the GL where the linear multi-channel SST (MCSST) algorithm is used. The buoy-satellite match-up is made within one image pixel in space (1.2 km at nadir) and within one hour in time.

For the NOAA-12 satellite, there are total of 679 matches in the three coastal regions (GM, SE and NE). The mean difference between satellite and buoy surface temperature (ΔT) matches is less than 0.50°C with a standard deviation of about 1.0°C. In the GL region, ΔT is 0.26°C during the day with a standard deviation of 0.83°C. The NOAA-12 night algorithm in the GL region generates a large bias of 1.52°C (82 matches).

The same statistics have been computed for NOAA-14 satellite measurements. For the coastal regions, ΔT is more accurate than that of NOAA-12. The bias is less than 0.2°C during the day and less than 0.1°C at night (448 matches). The standard deviation is about 1.0°C. In the GL region; ΔT is about 0.4°C at night (372 matches) with a standard deviation of 1.0°C.

1. INTRODUCTION

To derive the Sea Surface Temperature (SST) from satellite measurements has been a focus of numerous studies since the earlier 1970's (Anding and Kauth, 1970; McMillin, 1975; Barton, 1983; Llewellyn-Jones 1984, McMillin and Crosby 1984, McClain et al. 1985, McMillin et al. 1985; Walton, 1988; Barton et al. 1989; Minnett, 1990; Emery et al. 1994, Walton et al. 1998). The Advanced Very High Resolution Radiometer (AVHRR/2) onboard the NOAA series of Polar-Orbiting Operational Environmental Satellites (POES) is primarily designed for SST retrieval and cloud detection. POES satellites known as Advanced Television Infrared Observation Satellites (TIROS-N or ATN) operate as a pair to ensure that the data, for any region of the earth, are no more than 6 hours old. AVHRR has

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five channels, two visible channels at 0.6 and 0.9 μm, one short-wavelength infrared channel at 3.7 μm, and two long-wavelength infrared split channels at 11, and 12 μm. The spectrum of the three infrared channels is selected in the band that the radiation from the Earth's or a cloud surface is weakly attenuated. To determine the actual SST from the AVHRR radiation measurements, one must correct for the absorption and emission of atmospheric radiation. The split window method, which uses the channel 4 and 5 brightness temperature to calculate SST, is widely used for atmospheric correction. A summary and comparison of different split window algorithms can be found in Barton (1995). Operational multichannel AVHRR SST algorithms have been used to generate the high resolution SST imagery at NOAA National Environmental Satellite, Data, and Information Service (NESDIS) since November 1990. CoastWatch was fully operational in 1992 with one satellite. The second satellite was added in 1994.

Based on the split window theory, Multichannel SST (MCSST) was developed and used operationally at NOAA/NESDIS for global SST measurements beginning in November 1981. This algorithm assumes that there is a linear relationship between the difference of actual SST and the satellite measurement in one channel and the difference of satellite measurements in the two split window channels (channels 4 and 5). Therefore, the actual SST can be estimated using brightness temperatures measured with Channels 4 and 5. Walton (1988) considered a non-linear term in the further development of the MCSST algorithm and developed the Cross Product SST (CPSST) algorithm. A simple version of the CPSST algorithm, the Non Linear SST (NLSST), was implemented at NOAA/NESDIS for operational use in March 1990. A more detailed discussion of the development of the NLSST algorithm can be found in Walton et al. (1998). The coefficients in these algorithms are routinely obtained by performing regression between satellite retrievals and global drifting buoy data soon after each satellite's launch. These coefficients vary from satellite to satellite, and for daytime and nighttime measurements.

The satellite derived SST imagery has been widely used in studying atmospheric and oceanic problems. For some research applications, relatively low absolute SST accuracy is required as long as high relative accuracy is achieved, i.e., front and edge detection (Cayula and Cornillon, 1992; Kahru et al., 1995), and feature tracking and motion detection (Emery et al. 1991; Breaker et al. 1994). However, in some other studies, i.e., climate studies (Harries et al., 1983), more stringent absolute SST accuracy, normally less than 0.3°C, is required. To understand the satellite derived SST accuracy, various validation efforts have been performed by comparing the AVHRR measurements with moored buoy, drifting buoy and ship measurements globally as well as in different coastal regions.

For the global validation, AVHRR Global Area Coverage (GAC) data with a spatial resolution of 9 km/pixel and 8 km SST observation is normally used. Pichel (1991) used three months of NOAA-14 satellite and buoy matchups data set between March and May 1990 to validate the NLSST algorithm, and found global biases (i.e., mean satellite – buoy difference) less than 0.3°C with a standard deviation of about 0.7°C. Walton et al. (1998) analyzed a nine-year time series of satellite-buoy matchup between 1989 and 1997. They showed that the bias has stayed between -0.2°C and 0.4°C over the nine year period, while the scatter (i.e., the standard deviation) of the difference between the satellite and buoy SSTs improved from 0.8°C to 0.5°C for the daytime algorithm but remained about 0.5°C for the nighttime algorithm. After the Mt. Pinatubo Eruption in October 1992, the resulting stratospheric volcanic aerosols caused a positive bias in the nighttime SST measurements until June 1993. The GAC SST buoy matches are made within 25 km and 3 hours.

There are a lot of factors controlling the accuracy of the AVHRR SST measurement, i.e., optical properties of atmosphere such as the injection of aerosols (McMillin and Crobsy, 1984), atmospheric profiles (Yokoyama and Tanba, 1991), and these factors vary from place to place. In addition, a matchup made within 3 hours in the GAC data validation can give wrong result when the diurnal effects are considered (Cornillion and Stramma, 1985 Hawkins et al. 1993). Therefore, it is important to understand how accurate the AVHRR SST algorithm is in different coastal regions. That validation needs a satellite-buoy matchup data set closer in space and time. There have been a number of studies concerning regional AVHRR SST validation. Pearce et al. (1989) validated NOAA-7 and NOAA-9 derived SST using *in situ* boat measurements as ground truth in the coastal waters off Western Australia. They compared seven published split window algorithms and found that all algorithms yielded reasonably good results. The RMS error between the SSTs derived with two appropriate algorithms and boat measurements is