IMPROVING THE AVHRR ESTIMATES OF THE ADRIATIC SEA SURFACE TEMPERATURE

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ABSTRACT

Sea surface temperature (SST) is an important parameter in oceanography and meteorology due to its major influence on the exchange processes at the air-sea interface. Ever-increasing complexity and resolution of global and local, oceanographic, meteorological and coupled models further stress the need for accurate estimates of this parameter. Satellite measurements offer synoptic view and repetitive coverage of vast areas, but globally derived SST algorithms potentially conceal large regional differences. Regional performance assessment of SST algorithms is therefore an important task.

Two matchup databases of satellite and in situ SST were compiled at two locations, Rudjer Boskovic Institute (IRB) and Istituto Nazionale di Oceanografia e di Geofisca Sperimentale (OGS) with a view to validate the Adriatic Sea SST derived from locally collected NOAA-15, NOAA-16 and NOAA-17 AVHRR HRPT telemetry. Bulk SST data from 118 drifting buoys (mostly of the CODE type) have been used as the sea-truth. For the period between October 2002 and December 2003 165,252 matchup pairs were found satisfying 4-hours temporal and pixel-size spatial constraints. When more rigorous co-location constraints were set on atmospheric condition, temporal and spatial discrepancy (cloud-free, within a satellite pass, within a pixel) the number was reduced to 2560. The validation has been made for multi-channel SST (MCSST) algorithm, separately for the daytime and nighttime pairs.

Our analysis suggests that the use of regionally optimised retrieval coefficients improves the accuracy and statistics of the satellite derived Adriatic SST. When global coefficients are used in Adriatic absolute bias may exceed 0.3°C and scatter is typically around 0.7°C. With introduction of local coefficients bias drops to almost zero, and the scatter reduces to less then 0.6°C, for all three satellites and for both daytime and nighttime algorithms. Differences arising from different receiving and processing hardware and software turned out to be comparatively small.

1. INTRODUCTION

Sea surface temperature (SST) is an important parameter in oceanography and meteorology due to its major influence on the exchange processes at the air-sea interface. The AVHRR sensors on board NOAA satellites can provide dense and affordable set of SST data with global accuracy of ~0.5°C, but globally derived SST algorithms potentially conceal large regional differences. The Adriatic Sea can benefit from regional validation because of its land-locked position (Figure 1) and high variability of its SST fields.

Validation of remotely sensed SST relies on simultaneous in situ temperature measurements. Since infrared sensors measure SST of the upper micrometer layer (referred to as skin SST) it would be appropriate to have in situ measurements from the same layer. However, general lack of in situ skin SST measurements limits the practice to using bulk SST (temperature within 1 meter depth) [Li et al., 2001; Li et al., 2000; Shenoi, 1999]. With this problem in mind we used bulk temperatures (drifters-derived) as the sea-truth values for the Adriatic satellite SST validation. To gain additional confidence in the results satellite data acquired at two different receiving stations (Rudjer Boskovic Institute - IRB, and Istituto Nazionale di Oceanografia e di Geofisca Sperimentale - OGS, Figure 1) were compared with the same drifter dataset.

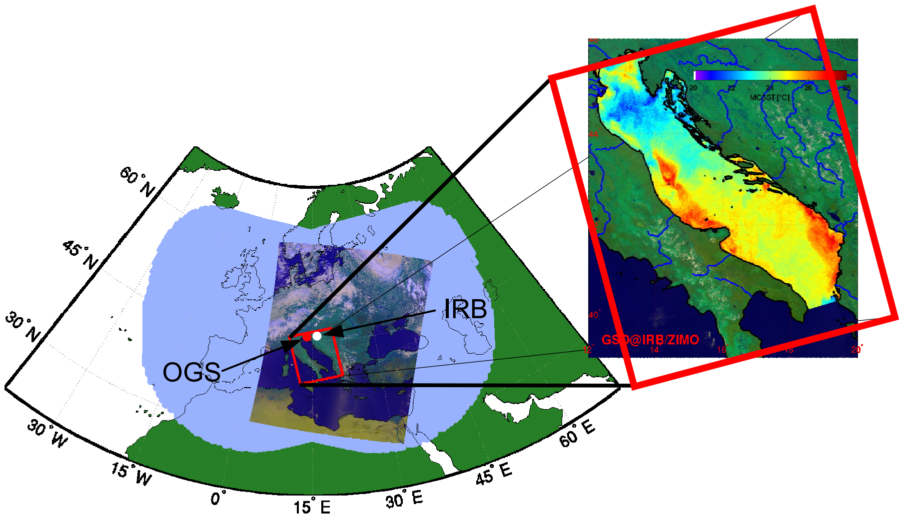

Figure 1. IRB satellite receiving station coverage circle (left) and the zoom on the Adriatic Sea with overlaid sea surface temperature map (right). The red and white points mark respectively OGS and IRB receiving station position.

2. DATA

2.1 In situ data

Drifters were released in the Adriatic Sea from October 2002 to December 2003. There were 118 drifters, majority of them (107) of the CODE type. Temperature sensor, positioned 40 cm below the surface, has accuracy of ±0.1°C. Positional accuracy was 200-300 meters for drifters tracked by Argos Data Collection System (DCS) on board NOAA satellites [Poulain, 2001]. Some drifters were additionally equipped with GPS system; their positional accuracy was 10 meters [Barbanti et al., 2005].

2.2 Satellite data

Data from the AVHRR/3 instrument on board NOAA 15, 16 and 17 were used to estimate the SST in the period for which the drifter data were available. Satellite data were acquired at two different receiving stations (Figure 1) and processed with different software packages (AAPP at IRB [Klaes, 1997]; TeraScan at OGS). Total of 4255 scenes was collected (1439 - NOAA 17, 1529 – NOAA 16 and 1287 – NOAA 15) with total average of 8.5 scenes per day. Multichannel sea surface temperature (MCSST) “split window” algorithm [McClain et al., 1985] was used to estimate the SST values for both daytime and nighttime scenes:

$$T_S = a_0 + a_1T_4 + a_2(T_4 - T_5) + a_3(T_4 - T_5)(\sec\theta - 1)$$

where T_S is the SST in °C, T_4 and T_5 are the AVHRR channels 4 and 5 brightness temperatures in Kelvin, θ is the satellite zenith angle, and a_0, a_1, a_2 and a_3 are the coefficients obtained by regression analysis with in situ measurements.

3. METHODS

Separate matchup databases were created at IRB and OGS sites to compare drifter and satellite derived temperature datasets. Each single drifter-derived temperature was paired with the satellite-derived temperature while meeting following conditions:

- Spatial: satellite and drifter data are collected within the pixel size spatial distance (cca. 1km);
- Temporal: satellite and drifter data are collected within the receiving time interval of satellite overpass (max. 15 minutes);
- Atmospheric: only cloud-free pixels are used;

Three things determine spatial difference between satellite pixel and drifter data: a) AVHRR spatial resolution (nominally 1.1km at nadir); b) AVHRR navigation error (reduced to within the spatial resolution of the instrument via automatic navigation adjustment [Bordes et al., 1992; Brunel and Marsouin, 2000]); c) Drifter navigation error (within 200-300 meters).

The IRB cloudmasking algorithm was based on different contrast signature and spatial signature tests [Saunders and Kriebel, 1988; Stowe et al., 1999] whereas OGS used cloudmasking based on [Notarstefano et al., 2003]. To avoid possible differences caused by different cloudmasking algorithms at the two sites only pixels declared clear in both matchup databases were used for validation. This restriction reduced the number of good matchup pairs to 2560, but improved overall cloudmasking quality.

4. RESULTS

4.1 Global coefficients

Two parameters were calculated to assess the performance of the global MCSST algorithm in the Adriatic Sea: *bias* (average difference between satellite derived and drifter measured SST) and *scatter* (standard deviation of the differences between satellite and in situ SST values). Results were separately calculated at IRB and OGS to assess possible processing scheme differences and to further certify the obtained results. Small bias differences between the IRB and OGS, ranging from -0.03°C to 0.07°C, demonstrate attained processing consistencies at the two sites.

The highest bias is obtained for NOAA 16 by night (-0.3°C), whereas bias almost vanishes for NOAA 15 by night. Daytime biases are always positive, between 0.1°C and 0.2°C, while nighttime biases span the 0°C to -0.3°C range. Scatter is between 0.5°C and 0.8°C with higher values during the day and smaller values over night. In global analysis, standard deviation is the same for all satellites (0.5°C) and bias is close to zero (John Sapper, personal communication).

4.2 New coefficients

To test the possibility of improving the retrievals of the SST in the Adriatic Sea a new set of coefficients was obtained by regression analysis. To that end original set of IRB matchup records is randomly divided in two subsets of equal size. Using the first subset a new set of MCSST algorithm coefficients is estimated and applied to the second subset [Shenoi, 1999]. For comparison purposes the global set of coefficients was also applied to the second subset and the results of both calculations are shown in Table 1. Results obtained with the global set of coefficients applied to the second subset are similar to the ones obtained by applying the global coefficients to the whole set; the differences in biases and standard deviations are ≤0.06°C.

		RANDOM IRB				
		GLOBAL		NEW		No. of matchups
		bias	scatter	bias	scatter	
NOAA 15	day	*0,16*	0,41	***-0,04***	**0,39**	28
	night	*-0,01*	0,52	***0,00***	**0,48**	84
NOAA 16	day	*0,09*	0,72	***-0,04***	**0,59**	363
	night	*-0,26*	0,66	***0,06***	**0,51**	543
NOAA 17	day	*0,22*	0,67	***0,04***	**0,62**	107
	night	*-0,18*	0,66	***0,04***	**0,52**	153
						1278

Table 1. Bias and scatter of SST residuals estimated using GLOBAL and NEW coefficients and applied to the randomly divided subset.

Biases obtained with the new coefficients are reduced to ≤0.06°C. Standard deviations are on average smaller by 0.1°C with the daytime values around 0.6°C and the nighttime values around 0.5°C.

5. CONCLUSIONS

This study suggests that regional, Adriatic optimisation of the AVHRR SST algorithms can provide improvements over the global usage. Adriatic biases estimated with global coefficients are ≤0.3°C and scatter ≤0.8°C. A new (tentative) set of coefficients reduces biases for all satellites to ≤0.06°C and scatter to 0.6°C (daytime) and 0.5°C (nighttime). With regional optimisation the differences between the daytime and nighttime biases are reduced from ≤0.4°C down to ≤ 0.1°C. These results suggest that the regional coefficients for Adriatic Sea may reduce bias and its day/night differences 4 to 5 times, but further validation with extended in situ dataset is required to declare new coefficients.

ACKNOWLEDGEMENTS

This study was supported by the Croatian Ministry of Science, Education and Sport via grant 0098113. The DOLCEVITA drifter project was supported by the United States Office of Naval Research.

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