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Reception and Processing of the Black Sea Surface Temperature Satellite Data for Georgian Water Area

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(Presented by Academy Member Tamaz Chelidze)

ABSTRACT. Procedures for the reception and processing of the Black Sea surface temperature satellite data are presented. The information of the hydro meteorological stations of the Black Sea coastal zone of Georgia is used for the quality control and quality assessment of these data. The Black Sea surface temperature satellite data identification and controlling methodology is created. *© 2010 Bull. Georg. Natl. Acad. Sci.*

Key words: *Black Sea, surface temperature, satellite data, quality control, quality assessment.*

The use of satellite information for determination of the Black Sea (BS) sea surface temperature (SST) is most effective. In oceanography as well as in meteorology and hydrology data reliability and accuracy is of key importance, especially when these data are obtained from remote sensing.

The infrared measurement method has been used since the 1970s to identify SST. The SST identification method is based on the physical rules of absolute black body radiation [1]. Radiation measurement is available for a definite section of spectrum.

Several satellite systems such as: NOAA-19, NOAA-18, NOAA-17, NOAA-16, NOAA-15, EUMETSAT and METOP-A are used for measuring SST. These satellites are equipped with high resolution radiometer (AVHRR), which continuously scans the Earth's surface and transfers the corresponding information to receiving stations.

Three main constraints exist to the determination of SST by remote sensing:

- Clouds impede the Earth's surface infrared radiation and consequently the identification of the earth's regions covered with clouds is impossible;
- The atmosphere absorbs part of the Earth's surface electromagnetic radiation. Atmosphere itself emits electromagnetic radiation and part of this radiation reaches the satellite sensor and part is detected after reflection from the Earth's surface;
- Solar radiation reflected from the Earth' surface reaches the satellite sensor.

In the case of the mentioned problems solution the identification of regions covered with clouds and reflective of solar radiation will be feasible. The method of passive measuring of various wave lengths radiation can be used for correction of atmospheric radiation.

In Table 1 AVHRR sensor channels characteristics are presented. The device transmits simultaneously 5 channels: channels 1,2,4,5 and 3a at daytime and 1,2,4,5 and 3b at night. Combination of these channels allows heat detection, which in turn determines the land, water, marine, clouds temperatures.

The regression equation for calculating cloudless SST is as follows:

$$T_s = a_0 T_i + a_1 (T_i - T_j) + a_2 \qquad (1),$$

Table 1.

AVHRR sensor channels characteristics

Channel	Area	Wave length (μm)
1	Visible	0.58-0.60
2	Reflected infrared	0.725-1.1
3a	Reflected infrared	1.58-1.64
3b	Radiated infrared	3.55-3.93
4	Radiated infrared	10.3-11.3
5	Radiated infrared	11.5-12.5

where T_i and T_j are radiation temperatures measured by two different infrared channels. In first approximation $a_0 \sim 1$ means that in this approximation SST is equal to the radiation temperature. The parameter a_1 $(T_i - T_j)$ characterizes atmospheric transparency. The last term compensates atmosphere brightness temperature difference on two different wavelengths.

Based on the adjustment of AVHRR radiation data with drifter's readings regarding SST information Bernstein [2] and McClain et al. [3] compiled two versions of algorithms for day and night measurements.

In the present study based on multichannel (MCSST) and nonlinear (NLSST) algorithms [4,5] the following regression equations are used for the determination of SST:

$$T_{MCSST} = b_0 + b_1 T_4 + b_2 (T_4 - T_5) + b_3 (T_4 - T_5)(\sec Q - 1) + b_4 \quad (2)$$

$$T_{NLSST} = a_0 + a_1 T_4 + a_2 (T_4 - T_5) T_{MCSST} + a_3 (T_4 - T_5)(\sec Q - 1) \quad (3)$$

where Q is the satellite zenith angle.

In the regression equations angle the a and b factors for various satellites are different. In Georgia the use of METOP-A satellite is more effective than NOAA satellite, as METOP-A measurement time is much closer to meteorological day and night measurement ones [6,7]. To determine SST values calculations were conducted using multichannel (MCSST) and nonlinear (NLSST) methods based on METOP-A satellite information. Satellite files were received from CLASS site (Comprehensive Large Array data Stewardship System.). These data are easy to use as the format of satellite data files does not change and the working program BEAM (Basic Envisat Toolbox ATSR and MERIS Platform) can use them without their preprocessing. To carry out calculations according to equations (2) and (3) the necessary index values of METOP-A satellite are given in Table 2.

In oceanography as well as in meteorology and hydrology data reliability and accuracy are of key importance, especially when these data are obtained by remote sensing. From this point of view several measures are realized. It is necessary to exclude cloudy pixels during calculations of SST values. The cloudiness has 4 values in satellite data received from the NOAA CLASS archive: 0 (cloudless), 1 (partially cloudless), 2 (partially cloudy) and 3 (cloudy). In calculations only the magnitudes of BS SST remained, for which cloud values were equal to 0.

The calculation accuracy of SST is reduced with satellite sensor zenith angle growth, as the Earth's surface radiation has to penetrate into atmosphere dense layers before reaching the sensor's sensitive element. Hence it is necessary to exclude those pixels for which the satellite zenith angle is more than 53^0. The pixels for which the Sun's zenith angle is less than 1^0 have to be also excluded, because in this case the Sun rays reflected from sea surface reach the sensor. In the case when the Sun's zenith angle exceeds 75^0 BS SST is calculated by night algorithm, and when the angle is less than 75^0, by the day algorithm.

It is important to carry out BS SST satellite data correction (Quality Control and Assessment {QC/QA}) by in situ observations carried out at the hydrometeorological stations of the Black Sea Georgian shore according to World Meteorological Organization (WMO) standards. The use of hydrometeorological data for BS SST satellite information QC/QA procedures is preconditioned by the fact that other data (buoys, drifters, ships of opportunity) are hard to obtain or are not available at all. The problem of such QC/QA is that this pair of data rarely coincides in time and is spatially slightly shifted. To form SST satellite and hydrometeorological database rotary files are created and processed.

BS SST satellite data QC/QA procedures are carried out step by step at pixel (stage I) and gridded (stage II) resolution. The major objective of the pixel resolution analysis is to identify and remove anomalies from the data, in order to avoid the damage of the final product at gridded resolution (gridded product) [8].

At the current stage satellite data QC/QA procedures have been realized for pixel resolution. The satellite data

Table 2.

Regression factors of METOP-A satellite for determination of SST values

MCSST	b_0	b_1	b_2	b_3
Day	-280.430	1.024530	2.10044	0.784059
Night	-276.075	1.008410	2.23459	0.736946
NLSST	a_0	a_1	a_2	a_3
Day	-253.308	0.934004	0.0724457	0.748044
Night	-255.063	0.939146	0.0750661	0.728430

(morning and evening values of 2007-09 summer months) are determined using the above-mentioned two methods. For BS SST satellite data QC/QA two hydrometeorological stations – Kobuleti and Poti – located on BS Georgian shore, are used. Based on the above-mentioned BS SST satellite as well as hydrometeorological databases for 2007-09 summer months are created.

For Kobuleti and Poti three nearest pixels are selected (Kobuleti, Kobuleti 1, Kobuleti 2 and Poti, Poti 1, Poti 2). The values obtained for these pixels were compared to corresponding hydrometeorological data. Based on the hydrometeorological data analysis it is determined that the 24 h gradient of BS SST is less than 3.0 ^{0}C. Hence BS SST satellite data is unreliable and is removed from the statistical row if its deviation from hydrometeorological ones exceeds 3.0 ^{0}C per 24 hr.

For 2007-09 summer months for the pixels of Kobuleti and Poti (Kobuleti, Kobuleti 1, Kobuleti 2 and Poti, Poti 1, Poti 2) the minimal deviations of SST satellite information from the corresponding data of hydrometeorological stations are determined. The statistical parameters are calculated and the histograms of anomalies are compiled. Based on the statistical analysis Kobuleti 2 was selected for Kobuleti and Poti 2 -for Poti. In addition, it was ascertained that the frequency of minimal deviations calculated by the MCSST method is more than by the NLSST one, which was also proved by correlation analysis. Therefore, for further studies pixel data for Kobuleti 2 (east longitude 41,76399^0, north latitude 41,82869^0) and Poti 2 (east longitude 41^0,75873^0, north latitude 42,10637^0) calculated by the MCSST method were used.

To create a statistical sequence high reliability data are needed whose deviation is less than 2 ^{0}C. As a result of correlation analysis the correlation between BS SST satellite and meteorological data was found to be 0.87 on the average. Positive deviations from hydrometeorological data are caused by satellite data automatic processing defects, namely by inaccurate geolocation of pixel coordinates and deviation to the land, which in cloudless weather may be noticed visually too. As is known, in the morning land temperature is higher than marine surface and it is the reason of positive deviations. This can be corrected by using GIS to achieve location of higher accuracy, which will enhance the statistical series of satellite observational data.

Significant negative deviation is recorded in the case if the selected pixel is covered with cloud but it failed to be excluded by the cloudiness algorithm.

An example of small deviation is presented in Fig. 1. For Kobuleti 2 the deviation is equal to -0.3°C, and for

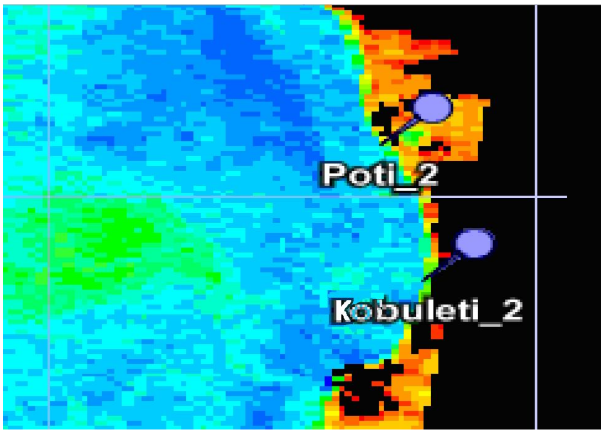

Fig. 1. Example of Small Deviation Given by Metop-A Satellite, 26 June, 2007, morning. Top of the pin indicates the corresponding pixel of the hydrometeorological station

Poti 2 it is -0.8 ^{o}C. In this case BS SST satellite data is identical to that of the hydrometeorological station.

The location accuracy of satellite data is fairly high, but in some cases an error of 2-3 pixel value is observed in the coastal strip, which can amount to several km taking into account the resolution (1.09 km) of AVHRR sensor. To correct this situation and specify the outline of the Georgian Black Sea coastal zone LANDSAT archive pictures are used. The obtained outline is presented in [9].

The conducted analysis revealed that BS SST data (Kobuleti, Poti), determined by the MCSST method, corresponds sufficiently well to its real values.

Based on the abovementioned research work the SST satellite data QC/QA methodology for the Black Sea Georgian shore is summarized as follows:

1. In calculations those pixels have to be excluded for which:
   - the satellite zenith angle exceeds 53º;
   - the Sun's zenith angle is less than 1^0;

2. If the Sun's zenith angle is more than 75º, then SST will be calculated by the night algorithm, and if the angle is less than 75^0 - by the day algorithm.

3. The calculated BS SST values are representatives for those pixels for which the cloudy index is equal to 0.

4. The Black Sea outline should be of the type as presented in [9] to achieve high geolocation accuracy for satellites with resolution of 30 m or less;

5. If the satellite data deviation in relation to hydrometeorological evidence exceeds 3.0 ^{0}C, then satellite data is considered to be unreliable;

6. Georgian BS SST satellite data have to be calculated by the MCSST method for corresponding pixels of Kobuleti (east longitude 41.76399^0, north latitude

41.82869^0) and Poti (east longitude 41.75873^0, north latitude 42.10637^0).

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გეოფიზიკა

შავი ზღვის ზედაპირის ტემპერატურის თანამგზავრული ინფორმაციის მიღება და დამუშავება საქართველოს აკვატორიისათვის

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ნაშრომში წარმოდგენილია შავი ზღვის ზედაპირის ტემპერატურის თანამგზავრული ინფორმაციის მიღებისა და დამუშავების პროცედურები. ამ მონაცემთა ხარისხის კონტროლისა და მონაცემთა შეფასებისათვის გამოყენებულია საქართველოს სანაპირო ზოლის ჰიდრომეტეოროლოგიური სადგურების ინფორმაცია. შექმნილია შავი ზღვის ზედაპირის ტემპერატურის თანამგზავრული მონაცემების მნიშვნელობების განსაზღვრის და ხარისხის კონტროლის მეთოდოლოგია.

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