The Use of Statistical Performance Measures in Validation of MERIS Case 2: Water Quality Processors in Nasser Lake, Egypt

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Abstract

Nasser Lake is considered the main and strategic storage of fresh water in Egypt, so that, the preservation of the lake and continues monitoring of its water quality is considered very important. Satellite-based remote sensing (RS) has become a useful tool for coastal and inland waters (management/preservation).RS contributes to estimating water quality parameters especially optical ones including suspended sediment (SS) and Chlorophyll-a (Chl-a) for the surface layer. Statistical measures will be used to validate MERIS Case 2 water quality processors, such as Case2 Regional (C2R), Eutrophic Lake and boreal Lake for Nasser Lake. Adjacency effect using Improved Contrast between Ocean and Land (ICOL) processor will be applied to images. A comparison between field and estimated SS and Chl-a will be conducted in case of using ICOL and without it. The results show that for SS, Eutrophic lake processor without using ICOL can be successfully used during maximum water level season. Also, C2R and eutrophic lake processor without ICOL can be used to estimate SS values during falling period (low flow season). While during rising period all tested processors failed to estimate SS. The statistical performance measure Chl-a indicates that eutrophic lake processor with using ICOL process is indicate a good results. It is recommend to have more field missions during multiple season(s) to better validate and/or create a new water quality processor for the case of Nasser Lake.

Keyword: Nasser Lake, MERIS image, Suspended Sediment, Chlorophyll-a

1. INTRODUCTION

The Aswan High Dam (AHD) was constructed in 1970, 7 km upstream the Old Aswan Dam (OAD). AHD has created one of the largest man-made reservoirs which called Aswan High Dam Reservoir (AHDR) is located in boarder between Egypt and Sudan with total length of 500 km, Egyptian part (Nasser Lake) has length of 350 km and the Sudanese part (Lake Nubia) is 150 km. The lake has design capacity of 162 milliard cubic meter at a water level of 182 m above mean sea level with total surface area of 6600 km2 at the same level. Since AHD full operation, the flood discharge of the Nile below the dam has been greatly modified and more than 98% of the sediment has been retained within the reservoir (Shalash, 1982). During flood season, sediments with high concentration is transported by water. SS has its great influence in water quality management as the high concentrations of SS affects the transmission of light in water, as well as transition of heavy metals and various micro pollutants (Zhang, 2011).

Since 1973, the first mission was assigned, to High Aswan Dam Authority (HADA) incorporation with Nile Research Institute (NRI), to collect data concerning the sediment deposition in Nasser Lake using hydrographic survey and measuring flow currents, suspended sediments and bed materials. At the end of 1970' decade, survey missions have taken into account water quality variable measurements (El Sammany, 2002). Traditional water sampling methods are able to quantify temporal changes in water quality at specific points. However, they are unable to effectively quantify water quality across the entire surface area. Also, due the expense of traditional monitoring programs, often, only critical locations are selected for monitoring. The advantage of remote sensing is that large areas of ground can be covered simultaneously, and water quality can be estimated over vast greater area.

Development of remote sensing techniques for monitoring water quality began in the early 1970s. These early techniques measured spectral and thermal differences in emitted energy from water surfaces. Substances in surface water can significantly change the backscattering characteristics of surface water (Jerlov, 1976; Kirk, 1983).In the perspective of remote sensing, waters can be generally divided into different classes (Morel and Prieur, 1977). Case 1 waters are those dominated by phytoplankton (e.g. open oceans). Case 2 refers to such waters that contain not only phytoplankton, but also other constituents such as suspended sediments, dissolved organic matters, and anthropogenic substances.

The MEdium Resolution Imaging Spectrometer (MERIS/Envisat) is primarily dedicated to ocean color observations covering open oceans and coastal zone waters (Doerffer et al. 1999), preliminary data from MERIS show that its imagery of large lakes is superior to that of other common ocean color sensors. The freely available processing toolbox for MERIS (BEAM, developed by Brockman Consult under contract to the European Space Agency) incorporates many of these methods into MERIS processing routines, offering the potential for improved interpretation of remote sensing signals over optically complex waters. A BEAM plug-in, the Case 2 Regional (C2R) processor, offers a dedicated Case-2 neural network based atmospheric correction procedure (Doerffer and Schiller, 2008a) and water constituent inversion algorithms (Doerffer and Schiller, 2008b), including two inland water modules for boreal and eutrophic lakes. Processors were validated using several remote sensing campaigns were conducted during the summer of 2007 in Finland (3 campaigns and 4 lakes), Germany (3 campaigns and 1 lake), and Spain (8 campaigns and 6 lakes). In addition to European lakes, validation activities were also conducted in Lake Victoria, Africa, using data collected before the start of the project, in 2003, 2004 and 2005 and in Lake Manzalah, Egypt, with data collected in 2007 (Koponen et al., 2008).In order to find out how the correction of adjacency affects changes the results of the Lakes processing the use of ICOL (Santer and Zagolski, 2009) processor was tested, ICOL processor found as a plugin in BEAM.

The main objective of this research is to use the statistical performance measures as indicators in validating the use case 2water processors. These include Case2 regional processor (C2R), Eutrophic lake processor and Boreal lake processor to find the spatial variation of optically dependent water quality parameters such as SS and Chl-a.

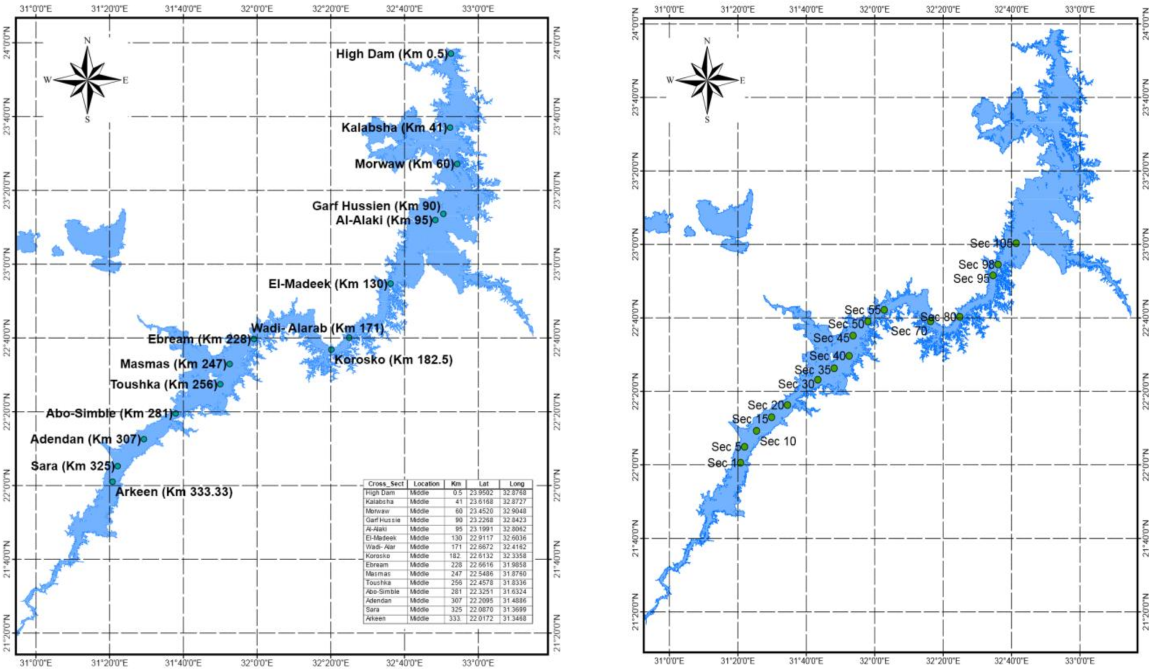
2. DATA COLLECTION

2.1. Field Data

Water quality data used through this research was collected during six survey missions in the period from 2003 to 2011. The annual field surveys were carried out by Nile Research Institute (NRI) and High Aswan Dam Authority (HADA). Figure (1a) shows the sample locations for water quality monitoring, and their geodetic coordinates. The indicated location is for all survey missions except for the 2010 mission as samples were taken every five kilometers from the Egyptian-Sudanese border until reaches near Allaqi section as indicated in Figure (1b).Water samples were collected vertically to represent water column at each sampling vertical samples were taken at 0.50 m below water surface,25%, 50%, 65% and 80% of water depth at each location. Water sample at depth 0.5 m under water surface is used through this research as it is the effective layer in remote sensing. Analyses of SS and Chl-a were used as water quality indicator following the Standard Methods for the Examination of Water and Wastewater (APHA).

2.2. Remote Sensing Data

MERIS will be used through this research. The primary mission of MERIS is the measurement of water color in the oceans, coastal areas and; lakes. Knowledge of water color can be converted into a measurement of water quality parameters such as chlorophyll pigment concentration, suspended sediment concentration and of atmospheric aerosol loads over water (ESA, 2006).MERIS was provided in three main spatial resolutions; Full-Resolution (FR), Reduced Resolution (RR) and Low Resolution (LR). Pixel in an FR image represents an area of 260 m × 290 m and in an RR image an area of 1,040 m × 1,160 m, and in LR an area of 4,160 m × 4,640 m. MERIS uses fifteen (15) spectral bands within visible and near infrared wavelengths. Each band has a programmable width and position within the 390nm to 1040nm spectral range of the electromagnetic spectrum(ESA, 2006).For the purpose of this study, the RS images were made available through TIGER Initiative project no. 14 under title of “Enhancing the Sediment Transport Modelling in the Nile Basin Reservoirs”.



a) b)

Figure1: Water Quality samples' Locations

MERIS full resolution (FR) level 1B quarter and full scenes were used in this research. This research will use MERIS images taken at07-Nov-03, 01-Dec-06 19-Nov-07, 01-May-09, 21-Aug-10 and 10-Oct-11.One image per each field trip was selected, the specific dates were chosen taking into account to select the most clear and cloud free images and to be at the middle of the mission period as much as it can. There are three reason to follow this approach in matching up process; first is that research was proposed after samples was taken, the second is that the change of water quality parameters occurred slowly except in flood season, the third reason is because the sampling date affected by the whole survey plan of monitoring program such as hydrographic survey. So that, it is not possible to get samples on the basis of scheduled MERIS overpasses. Six images were selected for purposes of validation of Case 2 water quality processors.

3. METHODOLOGY

3.1. Acquisition of Meris Images

Water quality processors are mainly developed in order to estimate the optically active substances found in water such as Suspended Sediment (SS) and Chlorophyll-a (Chl-a). Case2 water quality processors such as Case 2 Regional (C2R), eutrophic lake and boreal lake processors are found as a neural network that used to calculate Inherent optical properties of water. Improved Contrast between Ocean and Land (ICOL) is a processor developed to correct the increase in radiances due to adjacency effect. Figure (2) presents a flow chart of research methodology. Water quality processors and ICOL processor will be applied to the match up images for different field missions as follow:

i. ICOL processor was carried out to match-up images in order to correct the adjacency effect of water pixels.
ii. Case 2 water processors (Case 2 Regional, eutrophic lake and boreal lake processors) were applied to the raw match-up images, i.e., without using ICOL processor. Also, Case 2 water processors were applied to images resulted from ICOL processor.
iii. Pixel Data were extracted from the resulted images for two cases (with and without using ICOL processor) at location of each in situ measurement.
iv. A comparison between the predicted values of SS and Chl-a with the field measurements will be conducted to validate processors for Nasser Lake.
v. An evaluation of each processor will be performed in order to select the best water quality processor to be used for Nasser Lake and to what extent it can be applied in different seasons to assess water quality conditions.

The evaluation procedure was based on several statistical performance measures such as Fractional Bias, Correlation Coefficient, Normalized Mean Square Error, Geometric Mean Bias, and Geometric Mean Variance.

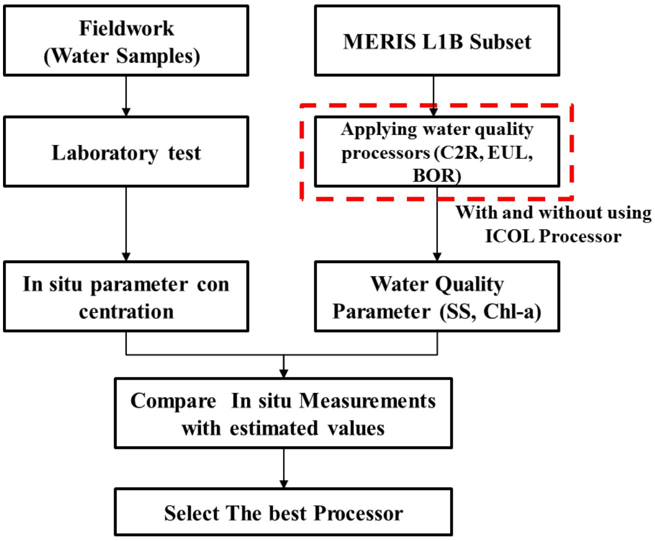


Figure 2: Flow Chart for Research methodology

3.2. Statistical Performance Measures

The statistical methods used here to evaluate the use of water quality processors was originated by Fox (1984) and modified by Hanna (1989), the method was used to evaluate several air quality models Hanna (1993) and also used in statistical analysis on wheat experiments (Patryl, 2011). The main idea is to find out the reliable and accurate model when compared to the real and actual measured values.

Two types of performance measures will be used in evaluation and selection of water quality processor to be used in Nasser Lake, the first is measure of difference which represent a quantitative estimate of the size of difference between predicted (C_P) and observed values (C_O), while the second is measures of correlation, which is a quantitative measure of association between predicted and observed values. The correlation coefficient between the observed and predicted values became a popular way of looking at the performance of a model. A perfect correlation coefficient is only a necessary, but not sufficient, condition for a perfect model.

Statistical measures used in the evaluation process are shown in Table (1). The criteria of good model were suggested by Kumar et al. (1993) for Normalized Mean Square Error (NMSE), Fractional Bias (FB), and Factor of two (FAC2) as shown in Table (1). Also there two additional criteria, for Geometric Mean Bias (MG) and Geometric Mean Variance (VG), were suggested by Ahuja and Kumar (1996) could be useful to test the reliability of the model.

Table 1: Formulation of used statistical measures and its criteria

Statistical Measure	Formula	Criteria of good model
Correlation Coefficient (R)	$r = \frac{\overline{(C_O - \overline{C_O})(C_P - \overline{C_P})}}{\sigma_{C_P}\ \sigma_{C_{Po}}}$	----
Mean Normalized Bias (MNB)	$MNB = \frac{1}{N}\overline{\left(\frac{C_p - C_o}{C_o}\right)} \times 100\%$	----
Fractional Bias (FB)	$FB = 2 \times \left(\frac{\overline{C_O} - \overline{C_P}}{\overline{C_O} + \overline{C_P}}\right)$	$-0.5 \leq FB \leq +0.5$
Normalized Mean Square Error (NMSE)	$NMSE = \frac{\overline{(C_O - C_P)^2}}{\overline{C_O} \times \overline{C_P}}$	$NMSE \leq +0.5$
Geometric Mean Bias (MG)	$MG = \exp\left(\overline{\ln C_O} - \overline{\ln C_P}\right)$	$0.75 \leq MG \leq 1.25$
Geometric Mean Variance (VG)	$VG = \exp \overline{[\ln C_O - \ln C_P]^2}$	$0.75 \leq VG \leq 1.25$
Factor of two (FAC2)	Fraction of data that satisfy $0.5 \leq MG \leq 2.0$	$FAC2 > 0.80$

In order to evaluate which water quality processor is valid, the following ranking method was proposed as follows:

All statistical performance measures, declared above, will be taken in the ranking process except Mean Normalize Bias as there is no defined criterion for best model found in literature. Also correlation coefficient will not be used in ranking. One degree will be given for each performance measure complies with the criteria for best processor, and zero for which not comply. The sum of these degrees for each processor divided by number of statistical measures, which is equal to five, expresses the ranking degree of each processor. Six ranking degrees are proposed in the following list:

- Not valid	0	- Good	0.6
- Poor	0.2	- Very good	0.8
- Accepted	0.4	- Excellent	1

4. RESULTS

4.1. Field Data Analysis

Figure (3) shows the survey missions period with changing water levels in Nasser Lake during the period 2001-2011. The first three missions and the sixth one were conducted during the period in which lake was at its maximum level, after the end of flood.T he fourth mission was conducted during the Lake level falling period, while the fifth mission was in the rising period. SS was measured during all survey missions except for the second one (2006) while Chl-a was measured during only two missions in 2007 and 2009.

Table (2) presents the descriptive statistics in means of maximum, minimum and standard deviation of the measured values of both SS and Chl-a in addition to the number of samples taken in each mission. The maximum SS value occurred during the fifth mission which took place during the start of flood period where water was fully loaded by sediments (Figure 2). The minimum value of SS occurred in the fifth mission as well, the reason of this is that the mission was just before the flood and all sediments settled down. The maximum value of standard deviation occurred in the fifth mission as there are big spatial variations in concentration of sediment between start and end of the lake. The maximum SS concentrations for other mission is ranging from 14 to 24 mg/l, which was very small compared to the maximum value during flood. The minimum values ranged from 2 to 6 mg/l, the variation in the minimum concentration of SS was not big as the northern part lake is not influenced by flood sedimentation. The measured concentrations of Chl-a during third and fourth missions were ranging from 10 to 13 mg/m^{3}for maximum and 3.5 to 4.5 mg/m^3 for minimum, this indicate that there is a small variation of Chl-a concentration during these two missions.

Table 2: descriptive statistics of measured SS and Chl-a at water depth of 0.5 m

			SS (mg/l)				Chl-a (mg/m^3)			
	From To	n	Max	Min	Mean	Standard Deviation	Max	Min	Mean	Standard Deviation
First Mission	23-Oct-03 15-Nov-03	10	20	6	10.20	5.20	-	-	-	-
Third Mission	15-Nov-07 24-Nov-07	11	28	3	12.82	8.88	13	3.5	7.50	3.074
Fourth Mission	24-Apr-09 08-May-09	11	14	5	7.45	2.70	10	4.5	8.05	2.162
Fifth Mission	21-Aug-10 31-Aug-10	16	84	2	23.06	25.99	-	-	-	-
Sixth Mission	04-Oct-11 15-Oct-11	9	24	2	8.67	8.40	-	-	-	-

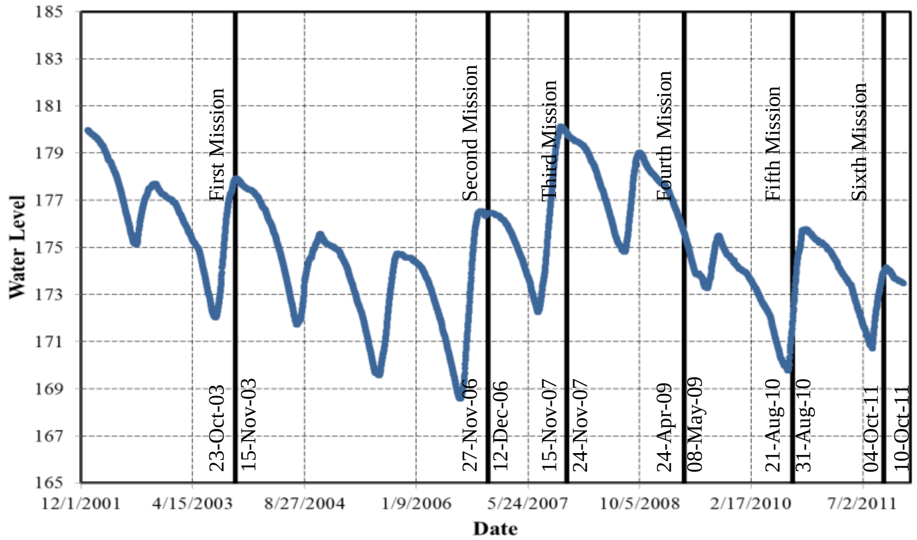


Figure 3: Survey mission with respect to water level change in period from 2002 to 2011

Validation of water quality processor will include only two parameters; SS and Chl-a as these processors were created to evaluate only parameters whose change in concentration affects the color of water, which called "optical parameters".

4.2. Validation of SS

Figure (4) shows the longitudinal profiles of SS for C2R, Eutrophic and Boreal Lake processors, without using ICOL processor, compared with the in situ measurements for the first mission, in addition to the spatial distribution of SS for three processors. The figure represents a sample of a group of figures created for all survey missions included in the research.

The comparison between predicted SS longitudinal profiles from the three processors shows that Eutrophic lake processor gives higher predicted values while Boreal lake processor gives a lowest value for all survey missions, this for with and without using ICOL processor. The spatial distribution of SS represented in the same set of figures also supports the previous observation. It is noted that a quite different behavior of boreal lake processor when using ICOL processor for fourth mission; most of predicted values along the longitudinal profile had lowest values and in some places in the lake predicated values were higher than two other processors.

Scatter plots between measured and predicted SS values for three processors are shown in Figure (5). A summary of the statistical performance measures is shown in, Table (3). The underlined bold numbers indicate that the value lies inside the limits of good model. Table (3) also shows the ranking of each processor according to ranking procedure which was illustrated in the previous section.

First mission has been performed in the period of maximum water level at the end of the flood. The behavior of water quality processors is shown in Figure (5a). The values of Mean Normal Bias are smaller than zero for all processors with and without using ICOL, which indicates a general underestimation by all processors. The maximum value of correlation coefficient (R) is observed for C2R without using ICOL processor. That is not evident that it is the best case as the other statistical measures for the same case is outside the accepted limits. The statistical measures indicates that Eutrophic Lake processor without ICOL is the most appropriate to use during this field mission, the ranking value of that processors is 0.8 indicating a very good degree for application, the values is inside the accepted limits except for Geometric Mean Bias (MG), but its value still the smallest compared to other processors.

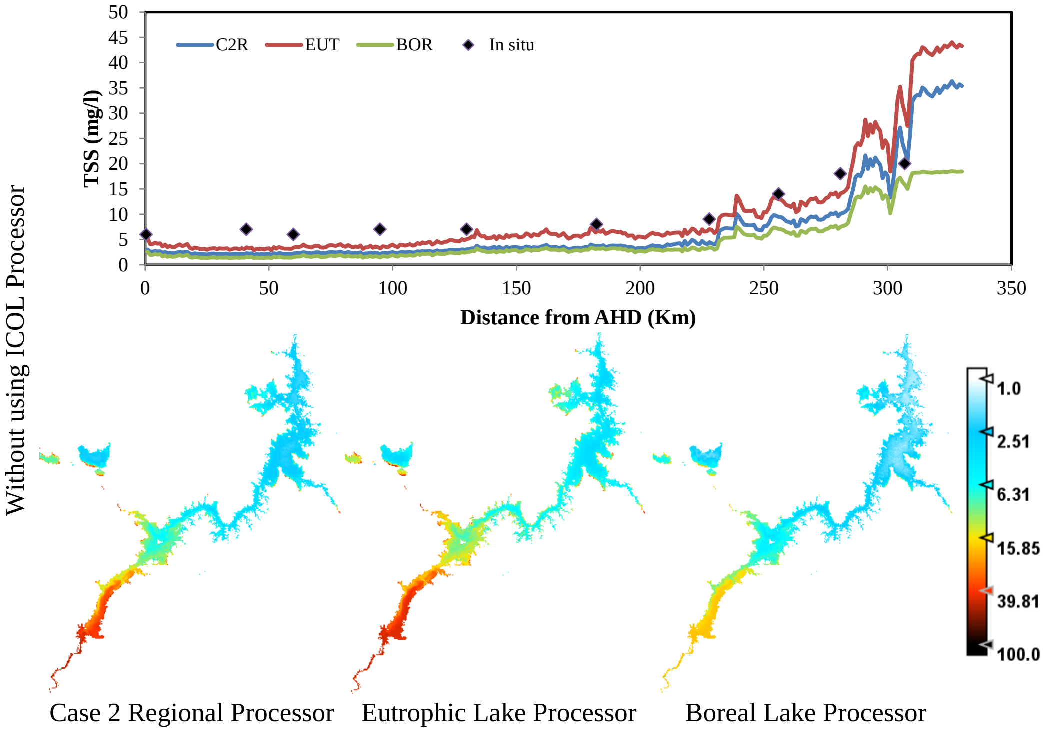


Figure 4: SS for First Mission (without ICOL)

Figure (5b) shows the relation between predicted and observed SS for third mission, figure indicate that values is around the 1:1 line for Eutrophic lake processor with and without using ICOL. The statistical measures for all cases indicates that there are three cases suitable for predicting SS; C2R without using ICOL and Eutrophic lakes processor using and without using ICOL. The ranking value for these processors, according to Table (3), is equal to one which indicates an excellent degree of ranking. The correlation coefficient for three processor ranges from a minimum value of 0.959 to 0.97, which indicates a good correlation for all three cases. C2R without using ICOL processor also gives a very good ranking as the ranking value is equal to 0.8 and the correlation between measured and estimated values equal to 0.963. So, it can also be used to estimate SS in this mission.

Although R values is relatively small for all processing cases during fourth mission, Eutrophic Lake processor and C2R processor without using ICOL processor indicates an excellent ranking of statistical performance measures, see Table (3), which comply with the limits of good model. The most appropriate processor according to the evaluation criteria is Eutrophic lake processor without using ICOL.

The scatter plot shown in Figure (5d) shows results of fifth mission performed at the start of flood period. The figure indicates a different behavior for all processor was observed during this mission, the relation between measured and predicted SS values show that, all processor fail to estimate SS value when it exceed 40 mg/l, as shown in the figure it gives a constant estimated value where the measured concentration is increased until reaches 84 mg/l. For values below 40 mg/l it gives a good trend with measured data. Some of statistical performance measure, such as FB, GM, and factor of two, comply with the criteria of good model but it cannot give a good indication for best model. The correlation between estimated and measured is not good as it does not exceed 0.48.

Table 3: Summary of statistical performance measures for SS

		Without ICOL			With ICOL		
		C2R	Eut_Lakes	Bor_Lakes	C2R	Eut_Lakes	Bor_Lakes
FIRST MISSION Nov-03	R	0.971	0.949	0.956	0.922	0.931	0.747
	MNB	-52.324	-26.397	-63.823	-69.039	-56.623	-70.556
	FB	0.645	**0.264**	0.882	0.916	0.635	1.044
	NMSE	0.517	**0.087**	1.119	1.156	**0.48**	1.784
	MG	2.144	1.389	2.853	3.646	2.595	3.94
	VG	1.869	**1.165**	3.205	6.792	3.16	8.683
	Fac2	0.500	**1.000**	0.000	0.1	0.3	0.1
	Ranking	0	**0.8**	0	0	0.2	0
THIRD MISSION Nov-2007	R	0.97	0.966	0.969	0.963	0.959	0.975
	MNB	-14.667	15.212	-38.916	-26.077	-1.028	-45.592
	FB	**0.122**	**-0.146**	**0.452**	**0.234**	**-0.035**	0.528
	NMSE	**0.03**	**0.054**	**0.305**	**0.078**	**0.035**	**0.402**
	MG	**1.182**	**0.876**	1.651	1.383	**1.033**	1.865
	VG	**1.047**	**1.035**	1.308	**1.164**	**1.049**	1.521
	Fac2	**1.000**	**1.000**	**1.000**	**0.909**	**1.000**	0.545
	Ranking	**1**	**1**	0.6	0.8	1	0.2
FOURTH MISSION May-2009	R	0.671	0.672	0.684	0.694	0.698	0.689
	MNB	-6.497	27.673	-33.075	-37.627	-17.839	-46.841
	FB	**0.05**	**-0.259**	**0.367**	**0.421**	**0.147**	0.579
	NMSE	**0.078**	**0.188**	**0.205**	**0.262**	**0.146**	**0.433**
	MG	**1.122**	**0.82**	1.586	1.718	1.31	2.02
	VG	**1.118**	**1.14**	1.398	1.55	1.257	1.929
	Fac2	**1.000**	**0.909**	0.636	0.636	**0.818**	0.545
	Ranking	**1**	**1**	0.4	0.4	**0.6**	0.2
FIFTH MISSION Oct-2010	R	0.48	0.442	0.36	0.472	0.435	0.376
	MNB	67.3	114.402	7.768	33.039	63.493	-8.247
	FB	**0.076**	**-0.084**	0.656	**0.142**	**-0.013**	0.694
	NMSE	0.681	0.619	2.287	0.748	0.667	2.384
	MG	**0.757**	0.6	**1.216**	**0.974**	**0.793**	1.382
	VG	2.001	2.542	2.164	1.848	1.983	2.05
	Fac2	0.750	0.375	0.563	**0.813**	0.625	0.625
	Ranking	0.4	0.2	0.2	0.6	0.2	0
SIXTH MISSION Oct-2011	R	0.976	0.972	0.968	0.973	0.967	0.968
	MNB	52.622	133.157	14.522	18.2	69.197	-18.627
	FB	**-0.257**	-0.583	**0.093**	**-0.135**	**-0.455**	**0.223**
	NMSE	**0.092**	0.468	**0.107**	**0.046**	**0.359**	**0.138**
	MG	0.67	0.448	**0.906**	**0.858**	0.6	**1.25**
	VG	**1.227**	2.081	**1.089**	**1.053**	1.337	**1.086**
	Fac2	**1.000**	0.556	**1.000**	**1.000**	0.778	**1.000**
	Ranking	**0.8**	0.2	**1**	**1**	0.4	**1**

Table (3) shows that there are three processors suitable for estimating SS inNasser Lake and give an excellent ranking degree during sixth mission. The processors are boreal lake processor with and without using ICOL and C2R processor with using ICOL. According toTable (3), C2R without using ICOL processor can be taken into account for sixth mission as the ranking value is 0.8 which means a very good compliance with the criteria of good model. Correlation coefficient (R) for all four select processors is ranging from 0.968 to 0.976, which gives a good correlation between field and estimated values.

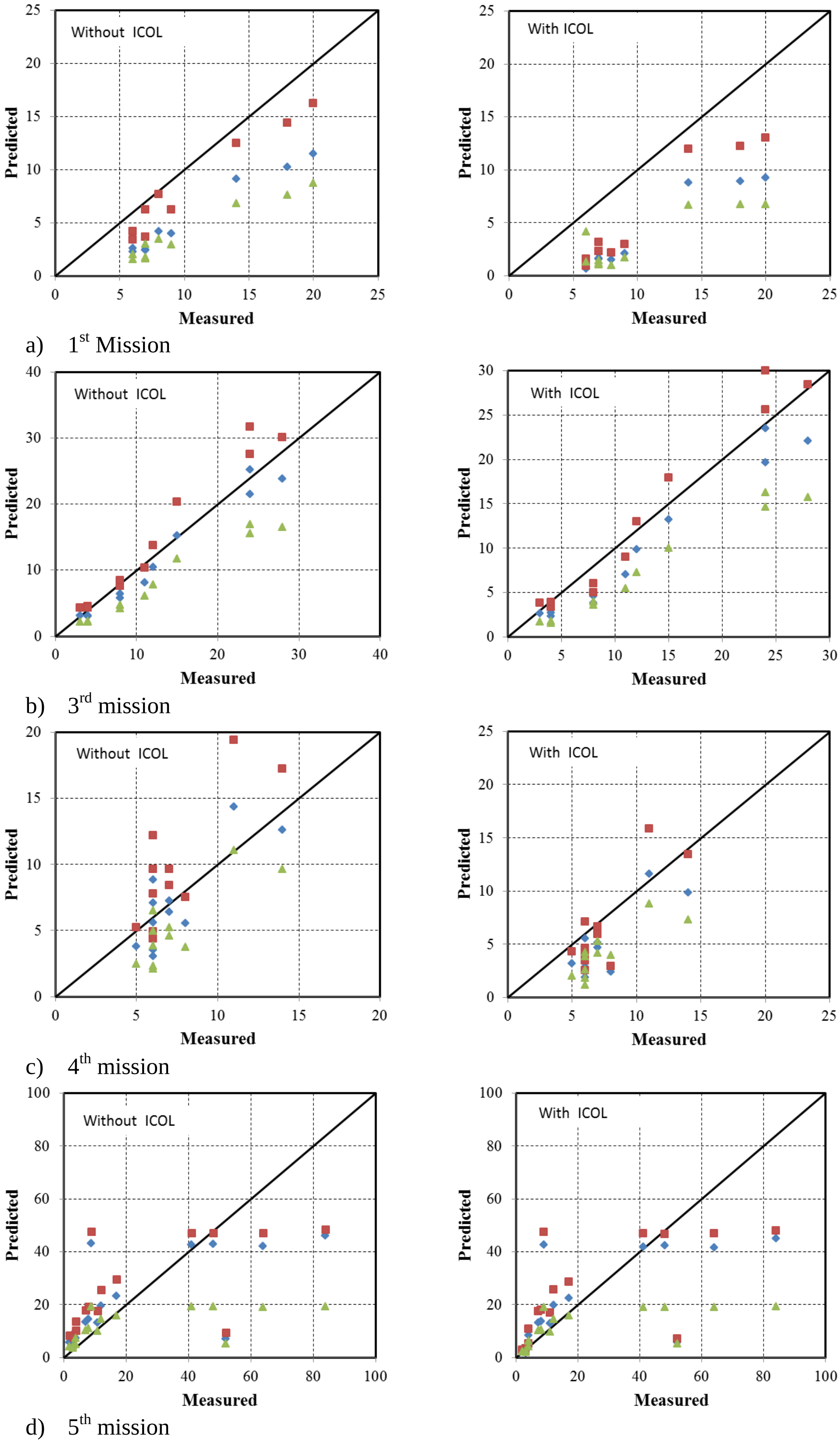
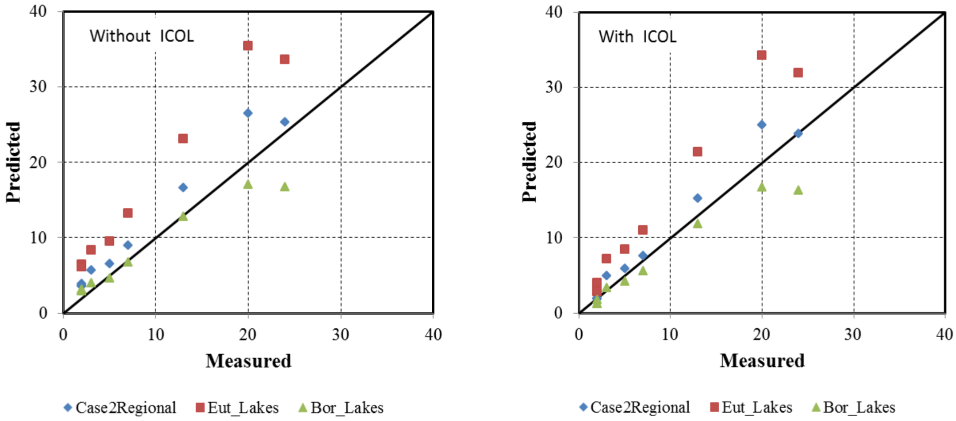


Figure 5: Measured verses predicted SS values



e) 6th mission

Figure 5: Measured verses predicted SS values (Cont.)

4.3. Validation of Chl-a

Validation of water quality processor to estimate Chl-a concentration in Nasser Lake will be based on the results from third and fourth missions. The validation will be following the same procedure as followed above in SS. Figure (6) shows the longitudinal profiles of Chl-a, estimate using three water quality processors, of third and fourth mission respectively.

The comparison of the three longitudinal profile shows that boreal lake processor gives a higher values than C2R and eutrophic lake processor with and without using ICOL processor while eutrophic lake processor give lower values, that can be supported visually using the spatial distribution maps shown in the same figures.

Figure (7) represents the scatter plot comparison between measured and estimated Chl-a values. Table (4) shows different statistical measures and ranking values. The evaluation of each mission will be discussed below for each mission. The correlation between measured and estimated Chl-a value is very poor during third mission, as indicated in table (4), the values do not exceed 0.0231, also the values of mean normalized bias is very high and indicated that there is a big scatter in data and the positive sign indicate that the processors give an over prediction for all of the processing cases except for eutrophic lake processor with using ICOL, the mean normalized bias is have the lowest value, in addition to the comply of good model criteria for FB, NMSE and MG. Table (4) indicates a ranking value of 0.6 for eutrophic lake processor with using ICOL, which mean, according to the ranking list shown before, that it give a good results compared to the in situ measurements.

Table 4: Summary of statistical performance measures for Chl-a

		Without Icol			With Icol		
		C2R	Eut_Lakes	Bor_Lakes	C2R	Eut_Lakes	Bor_Lakes
THIRD MISSION Nov-2007	R	0.0231	0.0021	0.000011	0.001	0.010	0.018
	MNB	79.390	72.679	324.959	62.751	-7.671	115.335
	FB	**-0.417**	**-0.362**	-1.114	**-0.301**	**-0.230**	-0.996
	NMSE	**0.387**	**0.346**	2.360	**0.341**	**0.331**	2.029
	MG	0.630	0.666	0.286	0.719	**0.774**	0.352
	VG	1.578	1.543	7.040	1.520	1.517	5.182
	Fac2	0.636	0.636	0.273	0.700	0.700	0.200
	Ranking	0.4	0.4	0	0.4	0.6	0
FOURTH MISSION May-2009	R	0.080	0.089	0.103	0.308	0.350	0.352
	MNB	87.795	74.755	341.599	28.854	16.981	155.765
	FB	-0.513	**-0.446**	-1.190	**-0.103**	**-0.005**	-0.720
	NMSE	**0.383**	**0.305**	2.418	**0.284**	**0.264**	1.278
	MG	0.576	0.617	0.250	**0.922**	**1.013**	0.523
	VG	1.567	1.450	8.225	1.408	1.389	2.776
	Fac2	0.727	0.727	0.000	0.636	0.636	0.545
	Ranking	0.2	0.4	0	0.6	0.6	0

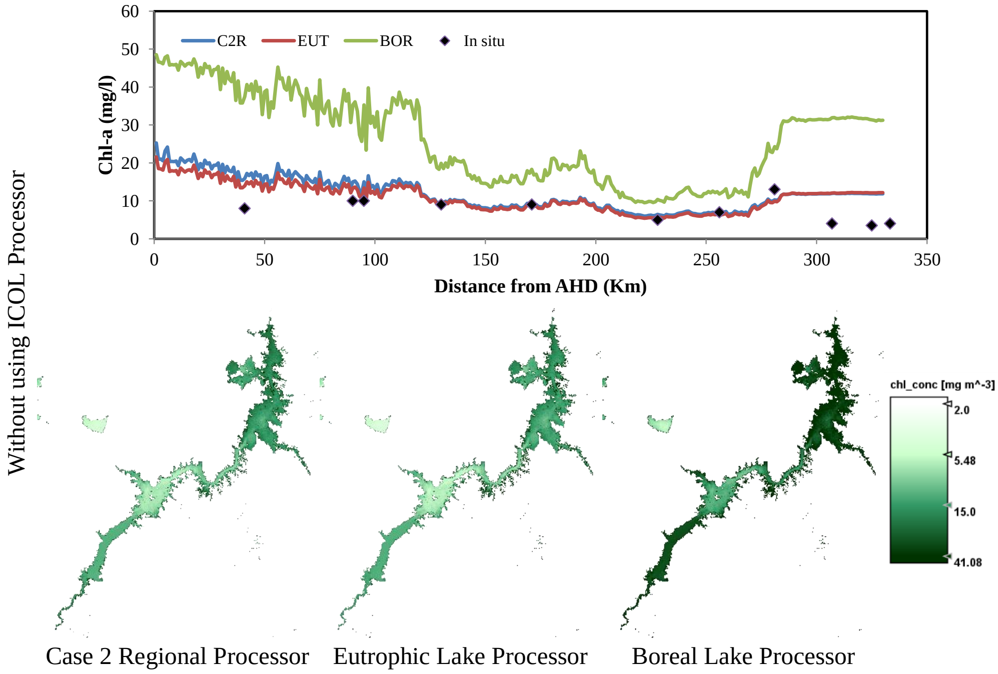


Figure 6:Chl-a for Third Mission (Without ICOL)

Statistical performance measures were shown in Table (4) which indicates that C2R and eutrophic lake processors with using ICOL comply with the criteria of good model for FB, NMSE and MG. The overall ranking values indicate the same value of 0.6 for both processors, which indicate a good ranking, while the correlation is very poor and did not exceed 0.35 between measured and estimated Chl-a values.

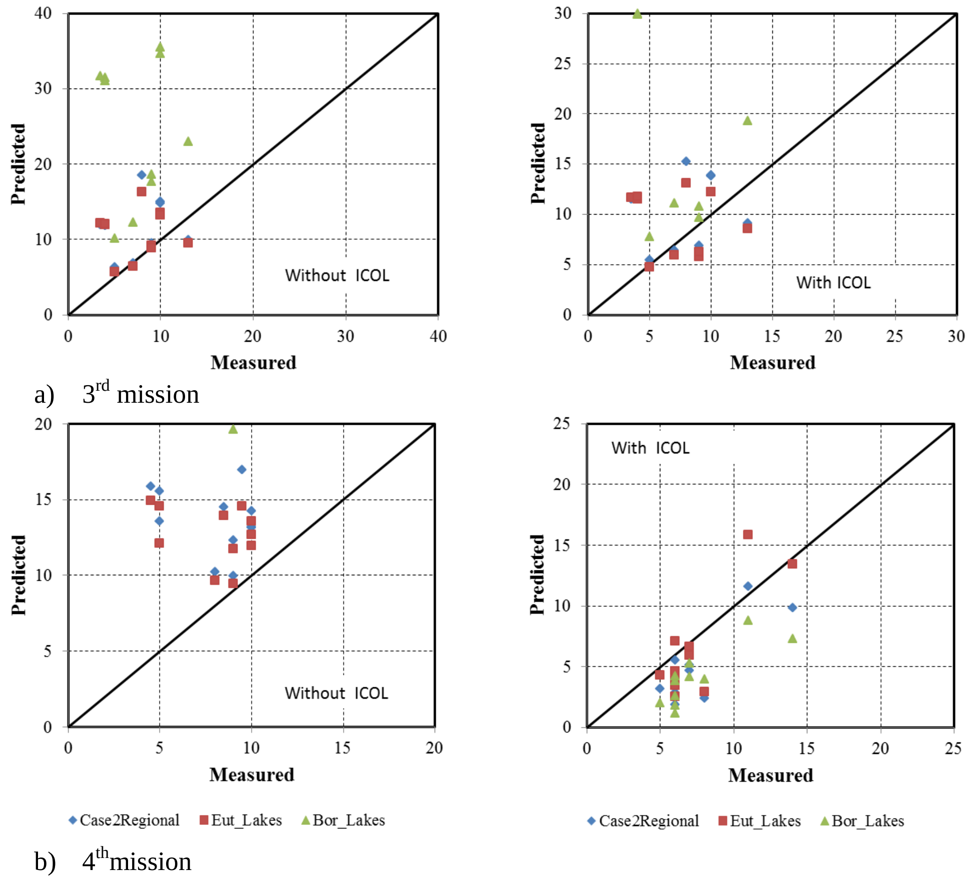


Figure 7: Measured verses predicted Chl-a Values

5. CONCLUSIONS AND RECOMMENDATIONS

The statistical performance measure and overall ranking of SS for First, third, and six missions were conducted during maximum water level, the evaluation and selection of water quality processors, for these missions, will be based on the sum of ranking values divided by three. The overall ranking values are 0.6 for C2R without ICOL, 0.67 for eutrophic lake processor without ICOL, and 0.6 for C2R without ICOL processor. So that, the most appropriate processor that can be used in this period is Eutrophic lake processor without using ICOL. While fourth mission were conducted during the falling period, C2R and eutrophic lake processor without ICOL can be used to estimate SS values as the overall rank value equal to one. The evaluation of water quality processor to estimate SS during rising period, fifth mission, did not indicate a specific processor to estimate SS for all lake during this rising period as all processors failed to estimate high concentrations.

The statistical performance measure and overall ranking of Chl-a for two missions indicated that eutrophic lake processor with using ICOL process will yield good results.

The intensity of field mission during different seasons is not enough to specify the suitable processor that can be used all over the year, for example, during the rising and falling periods SS was measured only once per each period. Also for Chl-a, there are only two mission surveyed in two different seasons. So that, it is recommend to have an extensive field program to validate and/or create a new processor for Nasser Lake.

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