THE VIOLET BREATH OF THE WORLD OCEAN*

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ABSTRACT

The examined phenomenon has one year period and influences on size of clear water areas of the world ocean. This one occurs in the subtropical zones of oceans on a large scale. The essence of one consists in a considerable increasing of areas of clear water in summer in comparison with winter in the northern hemisphere. There is the same process with shift in half a year in the southern hemisphere. The examples of historical retrospective by Interkosmos-21 MKS-BS and Nimbus-7 CZCS data, and recent products by OrbView-2 SeaWiFS are presented. The differences and features of clear water areas are considered in detail for five sites: North Atlantic, South Atlantic, North Pacific, South Pacific, and Indian Ocean. The executed investigation has the significant consequence to be useful for control over the global changes of the Earth's biosphere.

1.0 INTRODUCTION

Any large-scale, long-term information about ocean properties is necessary to improve our understanding of biogeochemical cycles. This work is the continue of the previous investigation (Suetin and Suslin, 1991) with new qualitative satellite data. The phenomenon with one-year period is examined in this paper. This one occurs in the subtropical zones of oceans on a large scale and influences on the size of clear water areas (referred to as CWA below). The CWA define as the areas, which have the value of the ratio of normalyzed water-leaving radiances in bands of 443 and 555 mn (referred to as "index" below) equal or more 6. The essence of one consists in a considerable increasing of size of CWA in summer in comparison with winter in the northern hemisphere. There is the same process with shift in half a year in the southern hemisphere. The examples of historical retrospective by Interkosmos-21 the multichannel bio-spectrometer (MKS-BS) (Bischoff et al., 1983) and Nimbus-7 the coastal zone color scanner (CZCS) data (Hovis, 1981), and recent products by OrbView-2 the sea-viewing wide field of view sensor (SeaWiFS) (Hooker and Esaias, 1983) are shown on fig. 1-2. Although the MKS-BS and CZCS missions were not designed to routinely collect global data, the measurements for all period of lifetime are adequate for mapping specific events to global scale in the intra-annual variability. All (different devices, methods of atmospheric correction and periods of time) it points that "the violet breath" of the world ocean is not instrument or atmospheric correction bugs, it takes place in nature. The first question, which naturally arises when considering this phenomenon is, what factors contribute to development of such strong variations? In contrast to (Yoder et al., 1993) and (Banse and English, 1994), the attention to the "simple" site in the open sea was attracted. On the one hand the "simplicity" of considered regions brings to minimum number of such factors. On the other hand it is not difficult to interpret with sun height angles of less then about 251 and relative simplicity of bio-optical properties of these waters.

Three mechanisms may contribute to these variations. The first one is underwater irradiance in upper euphotic zone which obviously influences on photosynthesis velocity -> phytoplancton <-> the yellow substance. The second one is the sea surface temperature (SST), which influences on photosynthesis velocity, too. The last one is the surface mixed-layer depth (MLD), which influences on biogene regime (nutrient fluxes). Strictly speaking, these three main factors are not independent, but they form necessary and sufficient basis for solving of our problem in these regions of the world ocean. The influence of these factors was considered for northern and southern hemispheres as whole and separately for five ocean sites: the North Atlantic, the South Atlantic, the North Pacific, the South Pacific, and Indian Ocean (referred to as NA, SA, NP, SP, and IO below, respectively).

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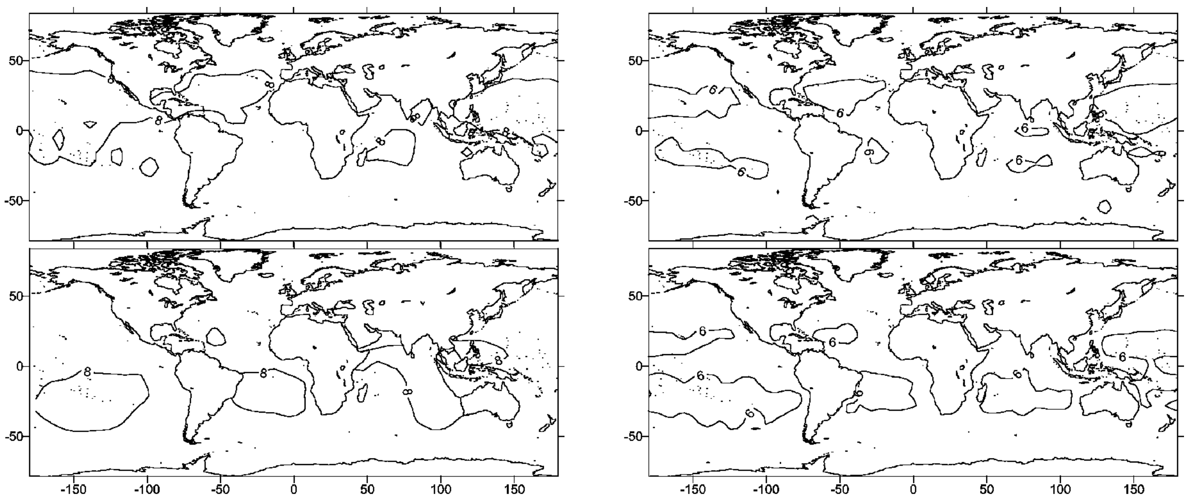

Figure 1. Seasonal Changes of Index (nLw449/nLw570) by MKS-BS Measurements from Interkosmos-21: Summer 1981 (up on left) and Winter 1981-1982 (down on left). Seasonal Changes of Index (nLw443/nLw550) by CZCS Measurements During 1978-1986 from Nimbus-7: Summer (up on right) and Winter (down on right). Note: nLwXXX, where XXX is Center of Spectral Band.

2.0 DATA PROCESSING

The basis of instrumental data set is the SeaWiFS level 3 binned data set for the period between October 1997 and September 2001 (reprocessing 3). Level 3 data is global gridded data that has been statistically collected into weekly grid squares (binned product) and contains the metadata describing the geophysical data (somehow, normalized water leaving radiances nLw at 412, 443, 490, 510, 555, and 670 nm) (Patt et al., 2000). The model generation of underwater irradiance was calculated as maximum of sun height angle (max h_{sun}) for given latitude during given day. Next, SST data product (referred to as JPL PO.DAAC product 016) consists of weekly averages of global Multi-Channel SST for the period between October 1997 and Janury 2001 (interpolated data set and night-time SST values from NOAA/NESDIS Global Retrieval Tapes were binned and averaged into eight-day measurements from ftp://podaac.jpl.nasa.gov/pub/sea_surface_temperature/). And the last is MLD data set calculated from climatological hydrographical data based on 0.51 criterion (Levitus, 1982). All data sets in the present study are arranged onto 1°x1° horizontal grids from the original data sets.

Choice of index (as ratio of nLw443/nLw555 values) as investigation parameter was made in follow reasons: possibility to compare of the result between different types of remote sensing instruments (MKS-BS, CZCS and SeaWiFS); to give more true and stable value in respect to errors of atmospheric correction and S/N instrument; to provide simultaneously high sensitivity to slight variations of chlorophyll-a concentration (total absorption) and a large size of CWA (index>6). At present this choice of spectral bands is optimal for open ocean waters and current NASA's operational method of atmospheric correction.

3.0 RESULTS

Results of simple analysis of possible influence of these main factors on the size of CWA present on fig. 3. Here weight of CWA is calculated as ratio of ocean area (with index more 6 separately for the southern and northern hemispheres) to all ocean area. The value of each parameter is calculated as average one within area of index > 6. The main result is that the seasonal cycle of size of CWA take place in nature with shift in half a year between the northern and the southern hemispheres, and SeaWiFS data shows it in detail (fig. 3c,d). Note, they have no correlation with sum of full-measurement grids (fig. 3a). The last one has enough high value of fullness (about or

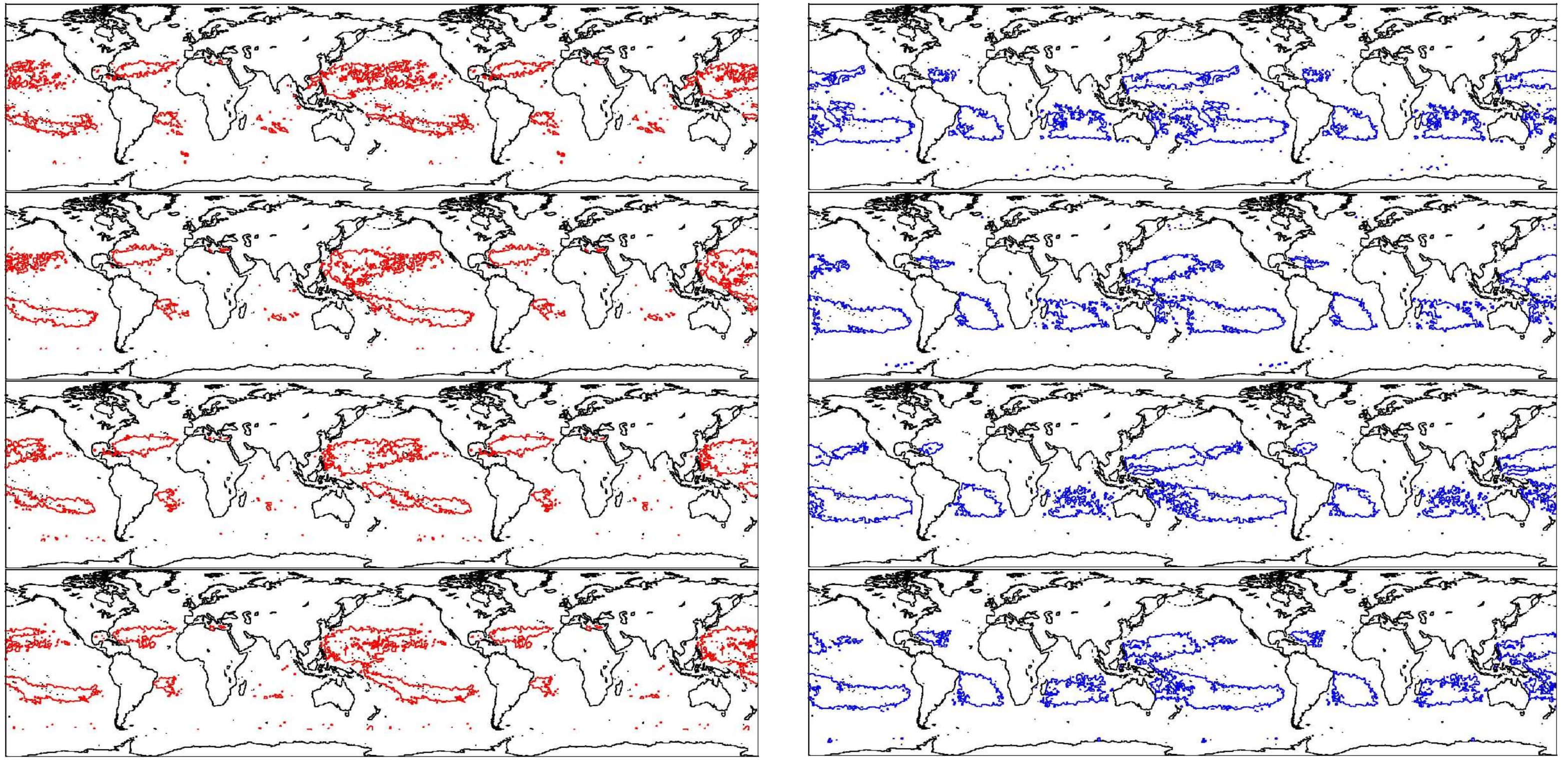

Figure 2. Inter-annual Variations of CWA in which Value of Index (nLw443/nLw555) is More 6, for Summer During Interval Sequential Day 201-208 (left column, red) and Winter During Interval Sequential Day 041-048 (right column, blue): 1998 (1st row), 1999 (2nd row), 2000 (3rd row), and 2001 (4th row), Respectively, by SeaWiFS Level 3 Binned Data.

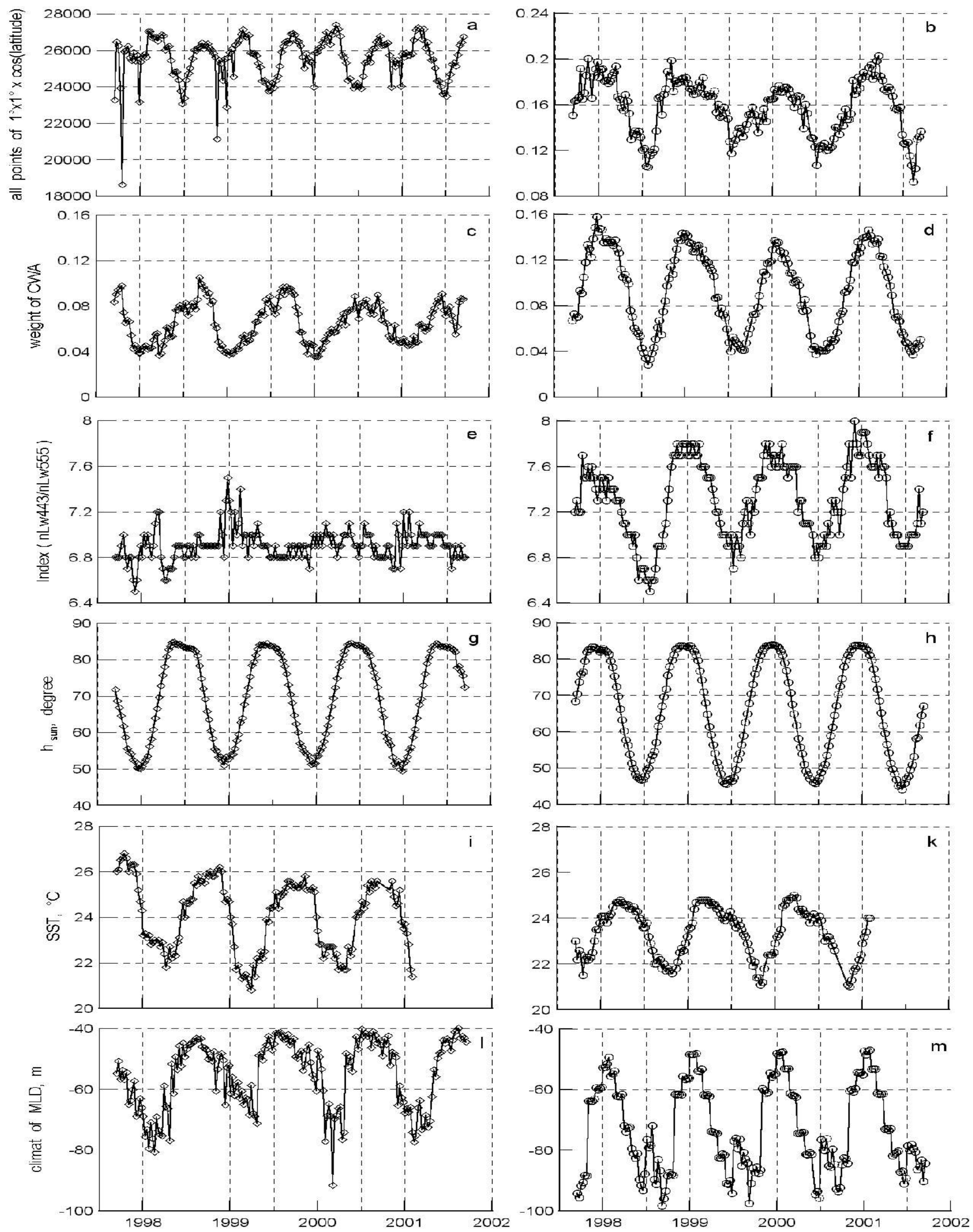

Figure 3. Time Analysis of 8-day SeaWiFS Level 3 Binned Product (Some of It Components) with Main Factors. Left and Right Plots are for Northern and Southern Hemispheres, Respectively, Except 1st Row. Sum of Latitude Corrected Grids is on (a). Weight of CWA with Index>6 as Time Function is on (b,c,d), where (b) is Sum of (c) and (d). Time Variability of Mean Values of Index is on (e,f), Sun Height Maximum is on (g,h), SST is on (i,k), and MLD is on (l,m). All Plots are within Index>6's Area.

more 90% of all ocean grids) and has a semi-annual cycle. The executed investigation of causal relations between the size of CWA and three main factors: the underwater irradiance, the surface water temperature and the surface mixed-layer depth, is showed that the major one is the first of them (see fig. 3). Because, for the phase of the underwater irradiance passes ahead on 6-7 weeks. For SST the phase lags behind weight of CWA variability on 7-8 weeks in the northern hemisphere and on 10 weeks in southern hemisphere. And for MLD the phase lags behind weight of CWA variability on 1-2 weeks. The physical essence of this phenomenon consists in seasonal variability of spectral composition (ultraviolet) and intensity of underwater irradiance in conditions of nutrient-depleted water. This variability controls phytoplancton concentration, which has hard relationship with yellow substance. The last one defines spectral composition of light in the blue part of spectrum outgoing from water surface. For five ocean sites results of simple analysis of possible influence of these main factors on the size of CWA separately are presented on fig. 4. The main result is that the seasonal cycle takes place in each ocean site with shift in half a year between the northern and the southern hemispheres.

4.0 FEATURES OF VARIABILITY AND IMPORTANT CONSEQUENCE

A lot of features of variability of size of CWA we can see on fig. 3-5. Decreasing of spectral reflectance at decreasing of underwater irradiance inside intra-annual cycle for small fixed region, which is typically at increasing of yellow substance (Kopelevich, 1983) (see fig. 6 and 7: plots 2 and 3). Oscillation the sum of weight of CWA (fig. 3b) has seasonal cycle as in the southern hemisphere that is consequence of the magnitude of weight of CWA in southern hemisphere which is more value than it in northern hemisphere on 50% (fig. 3c,d). Maximum of average index in the southern hemisphere is more value than it is in the northern hemisphere (fig. 3e,f). It takes place an asymmetry of weight of CWA slope within seasonal cycle, which is inverse for both hemispheres (fig. 3 c,d). The synchronous behavior of weight of CWA and mean index points to the same nature of biophysical processes occurred in IO, SA, SP, and NA sites. The exception to this rule it is NP site where mean index is almost constant in time series (fig. 5). The last shows specific character of biophysical processes in it would seem homolog sites. Apparently, the reason of it consists in nearness of NP site to Equator (fig. 5). Also, value of index in the SP site has absolute maximum (fig. 5). And that is more, for this site (and NA) a mean index increases during 1998-2001. Mean index has 2-year cycle for IO and SA sites. Next row of ocean sites of increasing of maximum value of index (and spectral reflectance, too) is true NA-IO-SA-NP-SP. Paradox consists in that NA site is in the end of this row (fig. 5). Fig. 2 and 5 illustrate inter-annual decreasing of weight of CWA maximum in the IO site (fig. 4) and shift of mean latitude in the direction of the South Pole. The last is specificity only for IO site. For other sites weight of CWA has asynchronously with shift of mean latitude and synchronously as rule with shift of mean longitude within annual cycle. Probably, shift of mean latitude is connected with change of underwater irradiance, and shift of mean longitude is connected with large-scale dynamics of the world ocean. Some of these features are obvious; others demand of its explanations. Summarising the features of our sites, we can say that the IO and NP sites are particular regions in contrast to SA, SP, and NA that have "ordinary behavior".

Important consequence of considerable physical phenomenon has useful property for control over the global changes of the Earth's biosphere. Observing for inter-annual differences as sizes, geolocations, phases and other characteristics of CWA in the form of regular trends out against a background to intra-annual cycle, we have an effective possibility for control of physical processes in any ocean (excluding Arctic ocean), that is why: (1) CWA are in all oceans, (2) they are large, and (3) this well-retrieved from satellite phenomenon has large response to slight variation of chlorophyll a concentration, or more correctly, total absorption of light in water in violet-blue part of spectrum (fig. 6: plot 1). For example, decreasing of sizes of CWA maximum during 1998-2000 years on 1.5-2% in absolute scale (fig. 3b) mainly it was consequence of processes occurred in IO site now (fig. 2). Other example, it is evolution of size of CWA in NP site during 1998-2001 from 0,09 to 0,07 in absolute scale (fig. 4).

5.0 FUTURE, FEEDBACK AND ACKNOWLEDMENTS

In future it would be very interesting to continue time series of SeaWiFS data and add the other sources of satellite data (POLDER, OCTS, MODIS, and etc.). Of course, it is necessary to exclude, if it's possible, climatological data and to use the real data set (about MLD) or replace it on other directly measurement

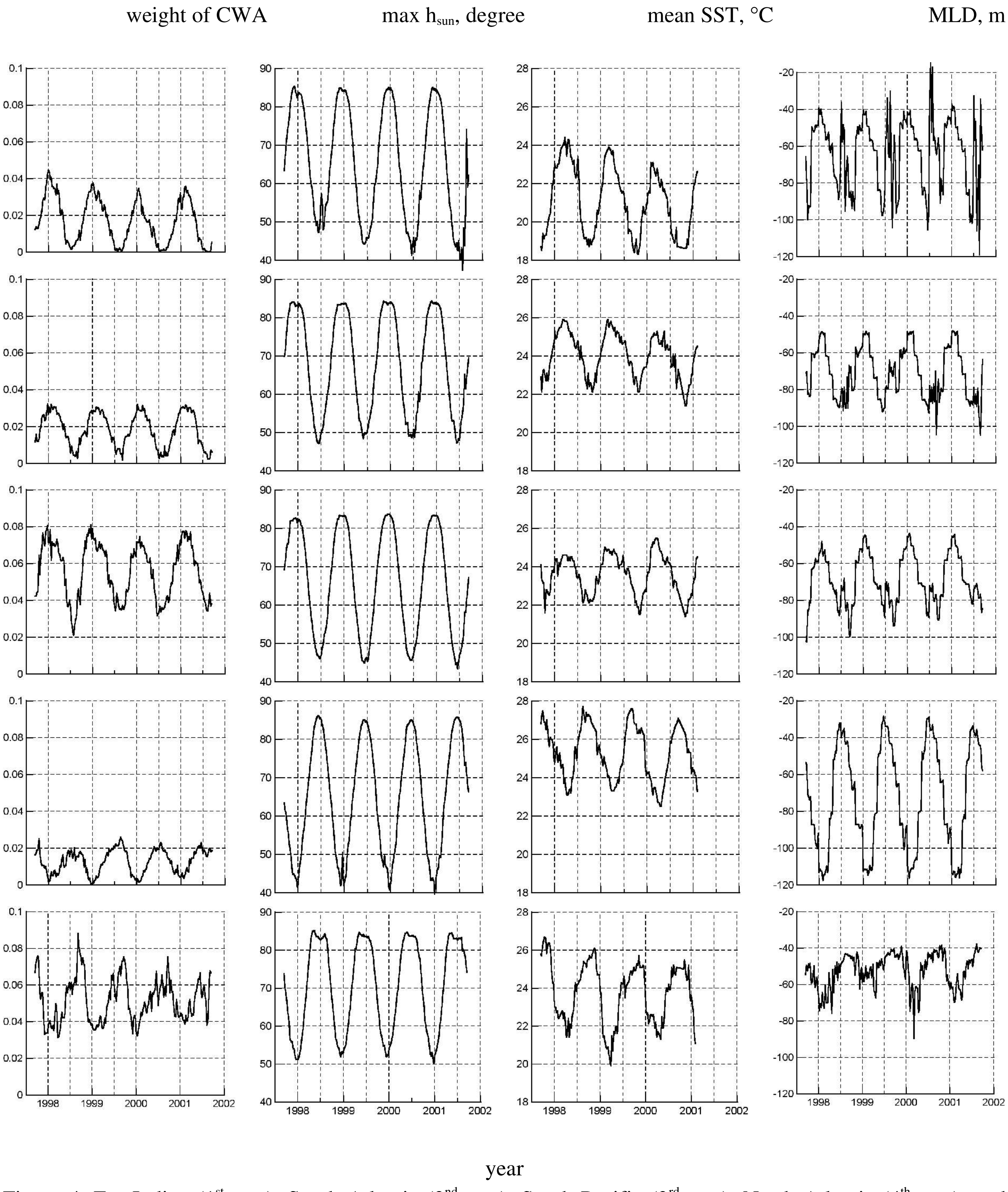

Figure 4. For Indian (1st row), South Atlantic (2nd row), South Pacific (3rd row), North Atlantic (4th row), and North Pacific (5th row) the Time Function of Size of CWA (1st column) and Main Factors: Maximum of Sun Height Angle (2nd column), Mean Value of SST (3rd column), and Mean Value of MLD (4th column) are Shown, Respectively.

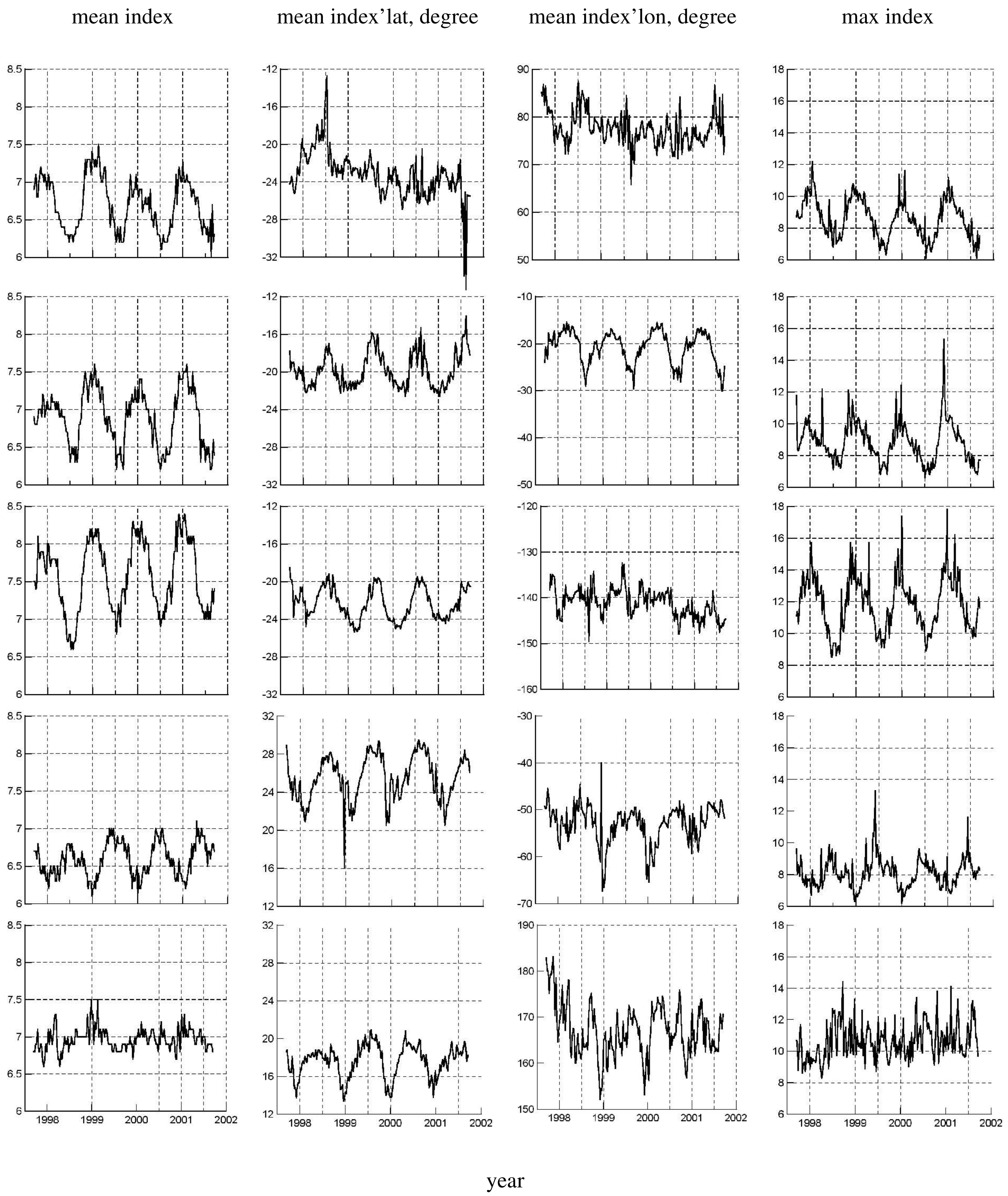

Figure 5. For CWA of Indian (1st row), South Atlantic (2nd row), South Pacific (3rd row), North Atlantic (4th row), and North Pacific (5th row) Sites the Maximum Value of Index (4th column) and Geolocation of Mean Value of Index (1st Column, Its Latitude is on 2nd Column, Its Longitude is on 3rd Column) are Shown as Time Function, Respectively.

parameter from space. Finally, it is to make estimation of influence of cloud fields (may be to use PAR). I am interested in any feedback, regarding the content this report via e-mail: otdp@alpha.mhi.iuf.net. Definitely contact me if you find errors or obvious omissions.

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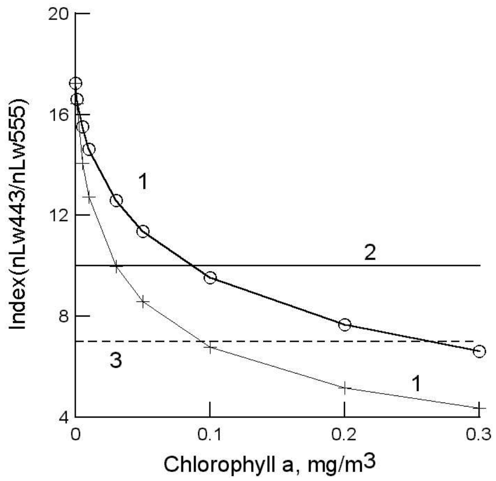

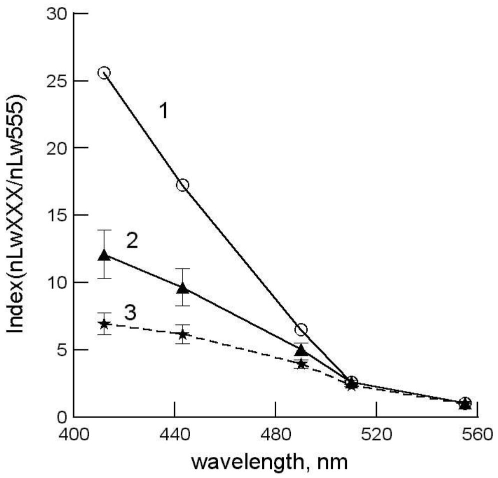

Figure 6. Left: (1) is Index (nLw443/nLw555) as a Function of Chlorophyll a Concentration for Different Models of Chlorophyll a Absorption. There are the Mean Values of SeaWiFS Index of South Pacific Region (lat=20°S-30°S; long=110°W-130°W) in Winter 1998 041-048 (2) and in Summer 1998 201-208 (3).
Figure 7. Right: Variability of Spectrums: (1) is the Clear Sea Water (Pope and Fry, 1997); (2) is Average Winter Spectrum in South Pacific Region (see fig. 6); (3) is the Same as (2) in Summer, where XXX is 412, 443, 490, and 510, Respectively.

6.0 REFERENCES

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