SEA RADIANCE COEFFICIENT SPECTRA OBTAINED BY REMOTE SENSING FROM BOARD A SHIP IN THE BLACK, BALTIC, ARAL AND KARA SEAS

Igor Goncharenko, Vera Rostovtseva, Dmitrii Khlebnikov, Boris Konovalov

P.P.Shirshov Institute of Oceanology RAS, Russian Federation; goncharenko@ocean.ru

ABSTRACT

For studying of water content and admixtures distribution in inland seas and coastal regions of oceans optical passive remote sensing from board a ship is of great importance. One of the most informative water characteristics is the sea radiance coefficient spectrum which we obtained with the special spectrophotometer developed for measuring the three values: upward sea surface radiation, radiance of the adjacent sky area (it is the area that contributes most to the reflection part of the sea surface radiation) and radiance of the horizontal white screen (it estimates the total illumination of the sea surface). After subtracting the reflection part from the upward sea surface radiation and dividing the result by the total illumination of the sea surface we obtained the sea radiance coefficient spectra. The measurements were made from board a moving ship in four seas characterized by various water properties: in Gdansk Bay of the Baltic Sea, in the north-eastern part of the Black Sea, in the western part of the Aral Sea, in the Kara Sea including the Ob Bay. The obtained sea radiance coefficient spectra were compared to the classification of the shelf sea waters developed for different water types and their peculiarities were explained. Comparing the types of the obtained spectra to the modeling results one can conclude that the Baltic Sea is characterized by the high content of dissolved organic matter, the Black Sea has abnormally high scattering, in the Aral Sea there occurs quite significant adsorption by some pigments though it is extremely saline and the Kara Sea differs greatly from the areas where it is similar to the open ocean waters to the areas of the river mouths with high content of dissolved organic and suspended matter. Then the original calibration method based on the spectrum of pure sea water absorption was used to avoid the impact of different weather conditions on the spectra formation and the absorption spectra of sea water in the chosen areas of the four seas were calculated. Using them we estimated the admixtures concentration and the efficiency of the suggested method in each case was discussed.

INTRODUCTION

Recently, investigation of oceans and seas by satellite remote sensing is a success. However, for thorough study of the coastal zones and inland seas some regional algorithms must be provided the is the problem in some cases. The possibility to solve this problem with the help of the special algorithm which is applicable for all waters is of great importance. In this paper we show the application of such method for four different seas.

METHODS

This paper presents the results of the study of waters in the four seas - the Black Sea, the Baltic Sea, the Aral Sea, the Kara Sea - using the passive optical remote sensing of water surface. As a result of measurements the sea radiance coefficient spectra were obtained. In the process of determining the sea radiance coefficient from the ship we used a spectrophotometer (AVANTES) measuring three values at each point. Firstly, the intensity of radiation rising from the sea, which includes the intensity of the backscattered radiation by the sea water and the intensity of light reflected by the sea surface. Secondly, the intensity of the sky, giving the largest contribution to the reflected radiation. Thirdly, the intensity of a white, horizontally disposed, diffuse reflector, which characterizes the sea surface irradiance. Other researchers used similar techniques for carrying

out optical measurements (1-4).

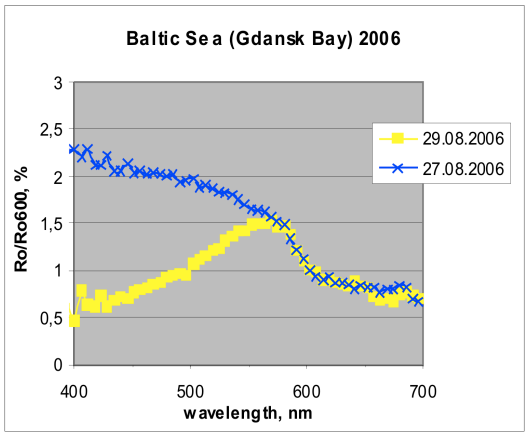
The received spectral signals were calibrated by the new technique described in (5). As a result, we received estimates of concentration of three main admixtures (chlorophyll, DOM and suspended matter).

Below, we will consider results of measurements for each of the seas.

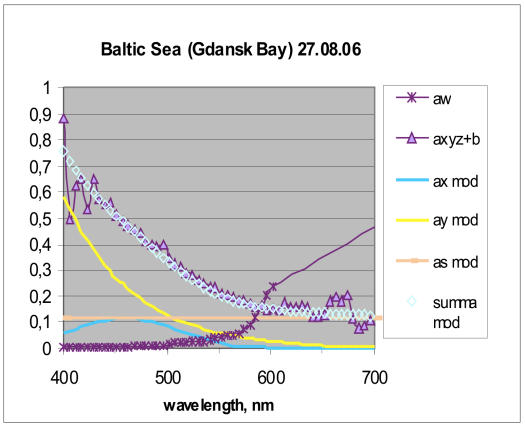
RESULTS

Baltic Sea

Measurements in the Baltic Sea were carried out from board of the scientific vessel "Oceania" of the Polish Academy of Sciences in August, 2006. The weather during the experiment was typical for this season: wind and roughness of the sea were average intensity, the sky overcast.



(a)



(b)

Figure 1: Baltic Sea. Sea radiance coefficient received remotely from a ship board (a), absorption spectra of sea water, calculated from the sea radiance coefficient (b). "aw" - pure sea water absorption, "ax" – absorption chlorophyll, "axyz+b" - total absorption of natural water admixtures, "as" - absorption of suspended matter, "ay" - absorption of "yellow substance", "summa" - total sea water absorption.

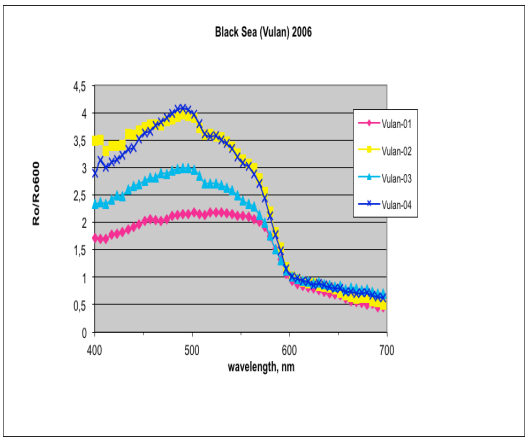
As a result of the measurements we received the following values:

Cp ≈ 0,5 ÷ 3,4 mg/m^3 (chlorophyll),
ay_{500} ≈ 0,01 ÷ 0,13 1/m (dissolved organic matter at 500nm)
as ≈ 0,12 ÷ 0,16 1/m (suspended matter).

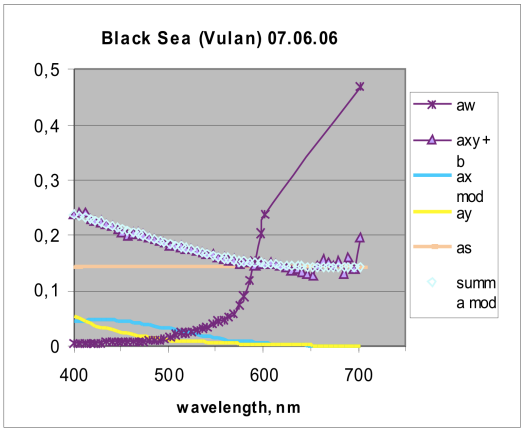
The presented values have the wide range as measurements were taken both in the high sea, and near the mouth of the Vistula River near the port Gdansk.

Black Sea

Measurements in the Black Sea were carried out from board of the scientific vessel "Ashamba" of the Russian Academy of Sciences in June, 2006. The weather during the experiment was following: roughness of the sea was average, wind speed was about 5-7 meters per second, the sky was partly cloudy.



(a)



(b)

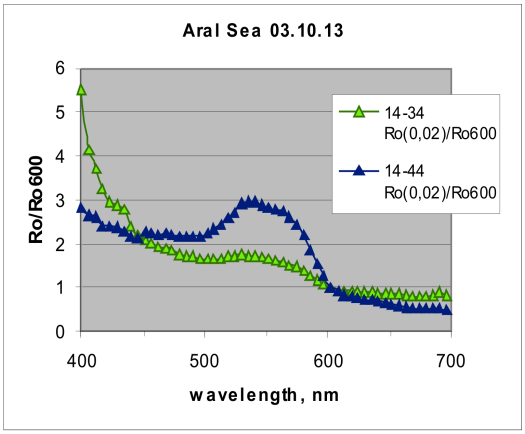
Figure 2: Balck Sea. Sea radiance coefficient received remotely from a ship board (a), absorption spectra of sea water, calculated from the sea radiance coefficient (b). "aw" - pure sea water absorption, "ax" – absorption chlorophyll, "axyz+b" - total absorption of natural water admixtures, "as" - absorption of suspended matter, "ay" - absorption of "yellow substance", "summa" - total sea water absorption.

As a result of the measurements we received the following values:
Cp ≈ 0,4 ÷ 1,3 mg/m^3 (chlorophyll),
ay_{500} ≈ 0,01 1/m (dissolved organic matter at 500nm)

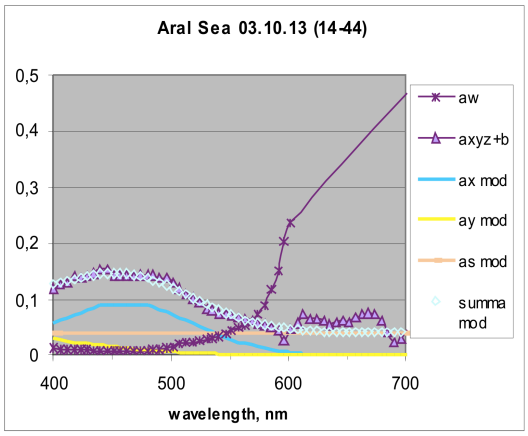
as ≈ 0,02 ÷ 0,14 1/m (suspended matter).

Aral Sea

On the Aral Sea we carried out measurements from rubber boats of the Uzbekistan Academy of Sciences in October, 2013. The weather during the experiment was typical for this season: wind and roughness of the sea were average intensity, the sky was cloudless.



(a)



(b)

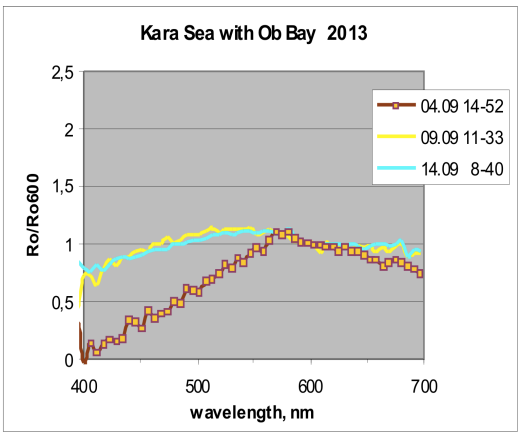
Figure 3: Aral Sea. Sea radiance coefficient received remotely from a ship board (a), absorption spectra of sea water, calculated from the sea radiance coefficient (b). "aw" - pure sea water absorption, "ax" – absorption chlorophyll, "axyz+b" - total absorption of natural water admixtures, "as" - absorption of suspended matter, "ay" - absorption of "yellow substance", "summa" - total sea water absorption.

As a result of measurements we received the following values:
Cp ≈ 2,7 mg/m^3 (chlorophyll),
ay_{500} ≈ 0,01 1/m (dissolved organic matter at 500nm)
as ≈ 0,04 1/m (suspended matter).

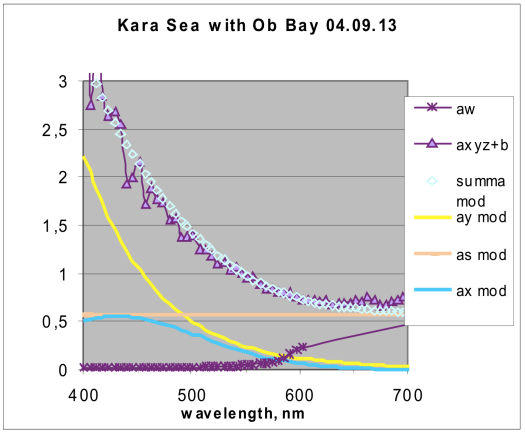
Kara Sea

Measurements in the Kara Sea were carried out from board of the scientific vessel "Professor Shtokman" of the Russian Academy of Sciences in September, 2013. The weather during the experiment was typical for this season: wind and roughness of the sea were average

intensity, the sky was overcast, the intensity of signals was very low.



(a)



(b)

Figure 4: Kara Sea. Sea radiance coefficient received remotely from a ship board (a), absorption spectra of sea water, calculated from the sea radiance coefficient (b). "aw" - pure sea water absorption, "ax" – absorption chlorophyll, "axyz+b" - total absorption of natural water admixtures, "as" - absorption of suspended matter, "ay" - absorption of "yellow substance", "summa" - total sea water absorption.

As a result of the measurements we received the following values:
Cp ≈ 0,05 ÷15,7 mg/m^3 (chlorophyll),
ay_{500} ≈ 0,2 ÷ 0,5 1/m (dissolved organic matter at 500nm)
as ≈ 0,03 ÷ 0,57 1/m (suspended matter).

The range of values is very wide because we carried out measurements both in the open sea and deep in the mouth of the Ob river.

CONCLUSIONS

Applying the suggested remote sensing method with new calibration to the four different seas is shown to be quite useful. The obtained values of sea water admixtures concentration, such as a chrolophill, dissolved organic matter and suspended matter, fall within the range of concentrations, measured by other methods in the four aquatoria under investigation (6-9).

In the nearest future we plan to upgrade measuring instruments for mapping the studied areas and comparing the results with the data of accompanying measurements and satellite data.

ACKNOWLEDGEMENTS

This work has been supported by Russian Scientific Fund Project N 14-50-00095.

REFERENCES

1 Matyushenko V. A., Pelevin V. N., Rostovtseva V. V., 1996. Measurement of the sea radiance coefficient with a three-channel spectrophotometer from aboard a research ship. Atmospheric and oceanic optics, 9. No. 05: 421-424.

2 Mobley C. D., 1999. Estimation of the remote-sensing reflectance from above-surface measurements. Applied Optics, 38(36): 7442–7455

3 Pelevin V. N., V. V. Rostovtseva, 2000. Estimation of “yellow substance” concentration in sea water by various contact and remote measurements data. Proceedings of SPIE, 4341: 459-465.

4 Hommersom A., Kratzer S., Laanen M. et. al., 2012. Intercomparison in the field between the new WISP-3 and other radiometers (TriOS Ramses, ASD FieldSpec, and TACCS). Journal of Applied Remote Sensing, 6: 063615-1 – 063615-21.

5 Rostovtseva V., 2015. Using inherent properties of seawater absorption for estimation of natural admixtures concentration from data of optical passive remote sensing of sea surface. In: 35th EARSeL Symposium – European Remote Sensing (EARSeL, Stockholm)

6 Wozniak B. and Dera J., 2007. Light Absorption in Sea Water (New York: Springer Science+Business Media, LLC) 454 pp.

7 Aibulatov N., Zavyalov P., Pelevin V., 2008. Peculiarities of hydrophysical self-cleaning of Russian Black Sea coastal zone near the mouths of rivers. Geoekologiya, No 4: 301-310. In Russian.

8 Zavyalov P.O. et al. 2012. The Large Aral Sea in the beginning of the 21th century. Phisics, Biology, Chemistry (Moscow. Nauka) 231 pp. In Russian.

9 Sukhanov I., Flint M., Mosharov S., Sergeev V., 2010. The structure of phytoplankton and primary production in the Ob estuary and adjacent Kara shelf. Oceanology, 50(5): 785-800.