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Satellite SAR and 'in situ' observations of phytoplankton in eutrophic waters

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The increased eutrophication of shelf areas and inland waters leads to intensive harmful algae bloom and therefore demands new methods of the bloom monitoring. Alpers et al. (2003) from the analysis of satellite optical and radar images of the ocean have concluded that algae bloom can be detected by radar arguing that phytoplankton produces biogenic films which result in the reduced radar backscattering. First direct proof of the relation between radar backscattering, biogenic films and phytoplankton have been obtained by Ermakov et al. (2013), and the physical mechanisms of radar backscatter depression were suggested based on damping of short wind waves due to elastic surface films as well as due to enhanced effective water viscosity.

This paper presents results of new experiments on remote sensing of algae bloom. Field observations were carried out on the Gorky Water Reservour from board a ship and from a small motor boat and were co-located and nearly simultaneous with TerraSAR-X image acquisition. Radar backscattering was measured from a ship with an X-band scatterometer, and acoustical scattering due to phytoplankton and the current velocity profiles were recorded with an acoustic Doppler Current Profiler (ADCP) Workhorse Sentinel 600 kHz from the motor boat, moving parallel to the ship track. Water samples and samples of biogenic films were collected from the boat and were analyzed in laboratory. Phytoplankton volume concentration was measured with an optical sensor in YSI 6600 probe, as well as using traditional methods of counting of phytoplankton cells with a Nageotte chamber. Analysis of characteristics of biogenic films sampled with a net method was carried out with a parametric wave method developed at IAP RAS which allowed us to retrieve the film elasticity and the surface tension coefficient. The parametric wave method was also applied to estimate the effective water viscosity in the presence of phytoplankton. Radar backscatter profiles were retrieved from TerraSAR-X images along the ship tracks and were found to be consistent with X-band scatterometer data. The experiments proved that SAR backscatter as well as scatterometer signal decreases with phytoplankton concentration, and the areas of enhanced phytoplankton concentration appear in satellite images as "dark" areas. Theoretical modeling of radar backscatter as a function of phytoplankton concentration was performed using retrieved values of the effective water viscosity, the film elasticity and the surface tension coefficient. The theory was shown to be in good agreement with observations.

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