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New approach for radiative transfer in sea ice and its application for sea ice satellite remote sensing

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In this paper the new analytical theory of the radiative transfer in the sea ice in visible and near IR regions will be presented. This analytical theory is based at the description of the optical properties of sea ice as a scattering medium that uses the newly developed approaches (the stochastic approach as applied to the problem of scattering by air inclusions in ice and the Rayleigh-Gans approximation for an ensemble of chaotically oriented large soft particles deployed for the description of the scattering by brine inclusions).Radiative transfer model of the system sea ice-atmosphere couples the above theory of scattering by sea ice and preliminary developed code RAY allowing the fast and accurate computations of the radiative transfer in any system consistent of plain scattering layers. On this base the software IRS (Ice Reflectance Simulator) was developed that allows a user to compute the radiative transfer in the system stratified aerosol-gaseous atmosphere-underlying sea ice in different conditions (snow covered ice, bare ice, summer Arctic ice with melt ponds). Particularly this software computes the signals at the input of satellite spectral optical instruments under various ice-atmosphere conditions.

The developed theory of ice reflectance and computer simulations performed with the IRS software were used for developing an algorithm for satellite remote sensing of sea ice conditions. Each pixel is supposed to consist of sub-pixels with following features: snow-covered ice, bare ice, and melt ponds. This algorithm allows one to retrieve the fractional coverage of each feature i.e. to retrieve the area covered by melt ponds at summer melting ice, snow characteristics for snow-covered ice, the pixel reflection characteristics (spectral and integral plane and spherical albedo). The last values are crucial for solution of various problems concerning climate change, and specifically for understanding and prediction of changes in Arctic environment. The algorithm includes newly developed atmosphere correction procedure and based on the developed theory of the reflection by sea ice and melt ponds. Up to now only the first verification of this algorithm has been performed as applied to the MODIS sensor with the use of the synthetic dataset. This dataset was obtained with the developed IRS simulator for various degrees of ice melting, various pixel compositions, different tmosphere conditions, and observation geometries. The outcomes of the retrieval procedure were compared to the input values into IRS and the satisfactory agreement was found. These first results look very promising. The verification of the developed technique for ice remote sensing with field data is planned to start in this year.