ATSR DATA AND HYDRODYNAMIC MODELS TO INVESTIGATE PHYSICAL PROCESSES IN LAKE BAIKAL, SIBERIA

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Abstract

A multi-layer numerical model is being developed in order to provide an insight into the hydrodynamic processes (surface manifestations of which can be observed with satellite data) occurring in the upper mixed layer of Lake Baikal, Siberia - an exceptionally clean lake. It is expected that the penetration of solar radiation through snow and ice-cover (which persists for several months) will have a strong impact on vertical and horizontal currents under the ice, due to differential heating between regions of clear ice and snow-covered ice.

In order to model the density-driven currents caused by this differential warming, the amount of solar heating beneath the ice cover must be known. This can be determined if the snow/ice thickness and reflectance are known. This study shows how ATSR thermal and visible wavelength data can be used to differentiate between types of surface (water, ice, snow etc.) and obtain top-of-atmosphere reflectance values, suitable for use as model input.

Keywords: Lake Baikal, modelling, hydrodynamics, ice, ATSR, diatoms

Introduction

Lake Baikal, the World's deepest and oldest lake, contains around 20% of all liquid fresh water. Many thousands of species live throughout the whole water column, but the focus of this study is the diatom population which resides primarily in the upper mixed layer. As this type of plankton has no means of self-propulsion, the organisms rely on the water motion for transport within the layer. The average sinking rate is about 3 meters per day, and without vertical water transport the entire population would soon sink below the photic zone and die. For the diatom species which are endemic to the lake, re-population from external sources (such as river inflow) is clearly an unacceptable means of re-population.

During the ice-free periods, vertical currents arise mainly due to wind driven and convective mixing, down to depths of 100-200 m. When the lake becomes completely ice-covered, wind driven vertical motions then become negligible, and the diatoms require some other method for re-suspension. Vertical convective motion could arise as solar radiation penetrates snow-free regions of the ice, warming the water towards the 4°C temperature of maximum density, resulting in density-driven convection. Strong horizontal currents (observed to be up to 10 cm s^{-1}) may be driven by density gradients due to differential heating between regions of snow-covered and snow-free ice.

A numerical model of the upper layer of Lake Baikal is currently under development. The incorporation of satellite data into the model should facilitate a qualitative reproduction of the current flow within this region. Vertical and horizontal flow in the model is driven by changes in the density of the water, determined from its temperature. The amount and depth to which solar radiation penetrates depends on factors such as the ice and snow thickness, absorption within the ice, snow and water (a function of extinction coefficients) and the reflectance (albedo) of the surface. Therefore in order to obtain realistic results from the model, each of these factors must be known.

The relatively large spatial coverage of ATSR satellite data compared to in-situ measurements makes it an ideal tool for studying the period of ice cover on the lake. Although snow/ice thickness cannot be determined from thermal or visible channel data, the presence of snow and ice can be detected in the thermal bands and values of reflectance can be obtained from the visible bands of ATSR-2. An average ice thickness, obtained from historical records, could be used as an initial thickness for all pixels classified as ice.

DETECTION OF ICE USING THERMAL INFRA-RED WAVELENGTH DATA

The three thermal infra-red channels of the ATSR instruments measure Brightness Temperatures (BTs) at wavelengths of 11 µm, 12 µm and 3.7 µm. The relationship between BTs and actual temperature is given by the Planck function and depends on the wavelength and the emissivity of the surface. For this reason, actual Sea Surface Temperatures (SSTs) can be accurately derived (to better than 0.5K) because the emissivity of water is known to have a constant value of about 0.99 at 11-12 µm (Zavody, 1995).

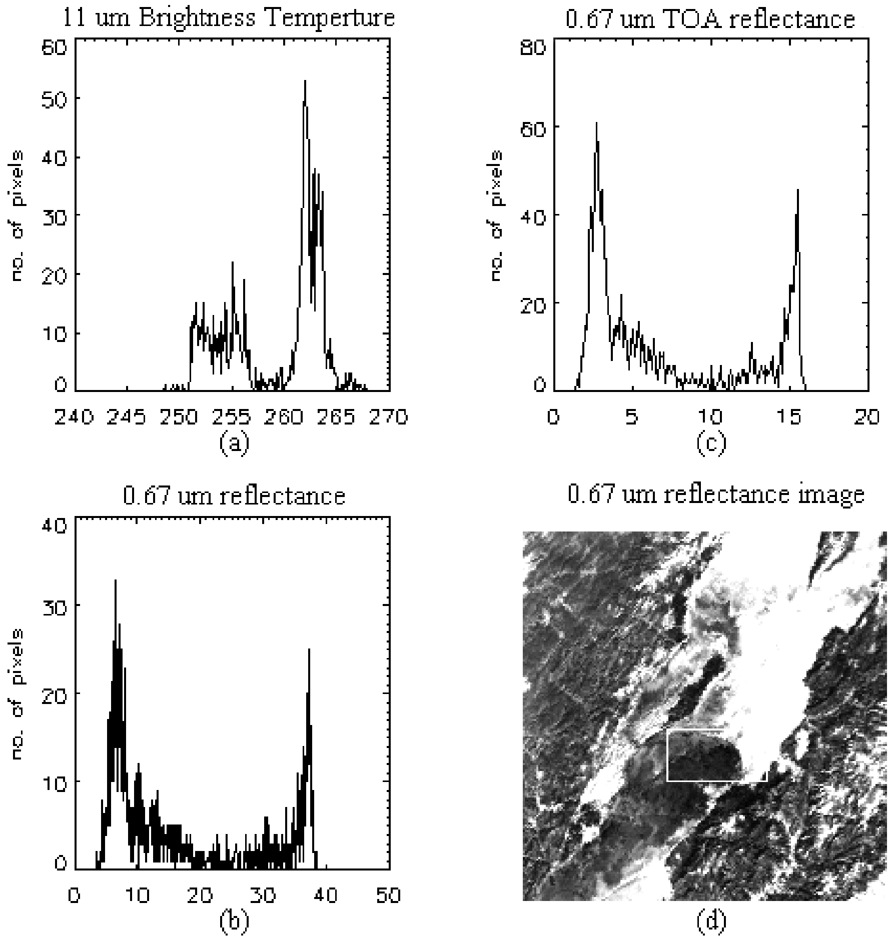

Figure 1. Histogram plots for lake pixels in a selected region, January 13th 1997. (a) 11 μm brightness temperature (K) histogram, (b) 0.66 μm uncalibrated reflectances (normalised count), (c) 0.66 μm TOA calibrated reflectance (%), (d) 0.66 μm image of part of Central/North basin, Lake Baikal. The white rectangle defines the region used in the above histograms.