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Characterization of the Sea-Ice Floes Issuing from Their Fractal Properties

Alexandre Chmel
Ioffe Physico-Technical Institute, Russian Academy of Sciences
St. Petersburg, Russia

Victor N. Smirnov and Leonid V. Panov
Arctic and Antarctic Research Institute
St. Petersburg, Russia

ABSTRACT

The satellite images demonstrate the fractal geometry of the fragmented ice fields in the region of the North Pole. The monitoring of the fractal patterns during a 6-week period revealed the variation of the floe fractal dimension interpreted as due to changes in the lead propagation mode. The analysis of the fractal patterns is potentially useful for predicting trends in the ice-cracking process.

INTRODUCTION

The fractal properties of some geophysical sites, such as fault systems (Okubo and Aki, 1987) or sea-ice floes (Rothrock and Thorndike, 1984) are well known, but the attempts to explain the mechanism of generation of the fractality are few (Erlingsson, 1988; Matsushita, 1985; Aksenov, 1994). Any applied investigations of fractal properties of ice-cover geometry are unknown to us. This preliminary communication is to demonstrate that the fractal parameters contain a piece of information concerning the properties and evolution of the crack-and-leads ensemble in sea-ice floes which could lead to a novel contribution to the treatment of the present and hardly diminishing problem of the assessment and prediction of sea-ice fragmentation.

In this study, we analyzed a series of AVHRR images from the NOAA satellite received in the Arctic and Antarctic Research Institute in the period from 03.31.99 to 05.14.99. All the images represent the same region in the Central Arctic. A typical photograph from this series is shown in Fig. 1.

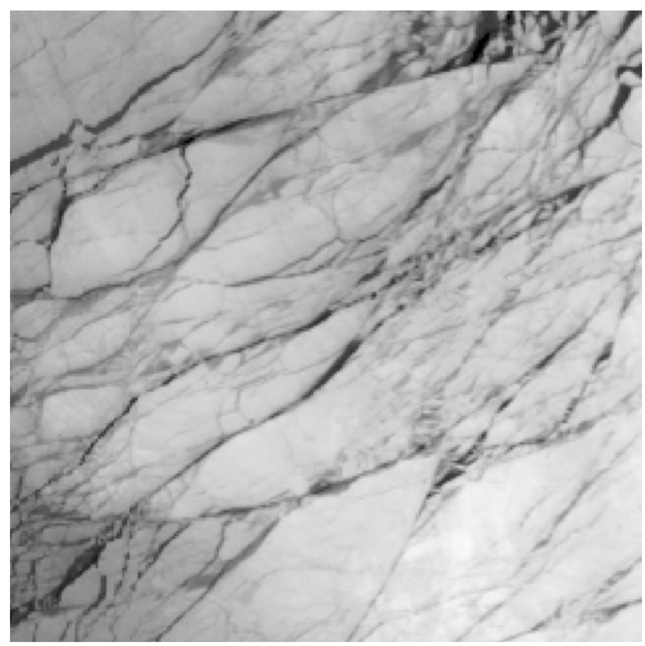

Fig. 1 A 300×300-km fragment of AVHRR image obtained from NOAA satellite 31 March 1999 in Central Arctic

FRACTAL PATTERN

The analysis was carried out using a conventional technique developed for revealing and studying the fractal geometry of a crack surface in solids. The method is based on the measurement of the area-to-perimeter ratio for ice-floe fragments restricted by leads and cracks. The computer processing was performed with the scale ruler being kept constant when measuring the lengths. The criterion of fractality was taken in the form (Mecholsky, Passoja and Feinberg-Ringer, 1989):

$$S^D = L^2 \tag{1}$$

where D is the fractal dimension of the ice-field fragment, and S and L are the area and perimeter of the fragment, respectively. Put in words, a fractality suggests that the self-similarity of ice floes of different real dimensions manifests itself in the proportionality between $\log S$ and $\log L$ with a coefficient equal to $2/D$. The sense of this analytical technique can also be illustrated by the following example. Let one try to draw a closed figure using equal straight portions of line ("rulers"). If the suggested figure is smooth—for example, a circle of radius R—then the perimeter would go to a constant value (to $2\pi R$ in the given example) with a reduction in the length of the "rulers". Otherwise—that is, in the case of a fractal figure—the perimeter length would grow infinitely in accordance with the power law. However, in the latter case, the ratio between the area and the perimeter will be the same at every step of the "ruler" truncation.

Fig. 2 shows $\log S$ versus $\log L$ plots calculated from the computer-treated images obtained on 3 April, 12 April and 14 May 1999. The range of plots was limited from below by the

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