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ANALYSIS OF SEA ICE COMPACTNESS BY IMAGE PROCESSING

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Abstract: A personal computer aided image analyzing system that can assess sea ice condition is described. The sea ice is photographed by a video camera from the ship. The shape of sea ice and the sea ice compactness are obtained by the system.

1. Introduction

Variations of sea ice extent, especially of Antarctic sea ice extent, have long been considered to influence global climate. Therefore the measurement of the interannual variations of the Antarctic sea ice is important (ALLISON, 1989). Monitoring of sea ice is also important for ship navigation. While satellite data give us a great amount of information about ice condition (COMISO and ZWALLY 1982; ZWALLY *et al.*, 1983), there still remains a need for *in-situ* validations (COMISO *et al.*, 1984; JACKA *et al.*, 1987). Visual observation, however, requires a great deal of labor, and has a limit in the ability to estimate ice compactness quantitatively.

In this paper, a new system which measures the ice compactness and ice shape by means of processing video images is proposed. Using the system, sea ice characteristics in the Antarctic Ocean were analyzed.

The sea ice image was recorded on board between Fremantle and Syowa Station in 1988 by the members of the 30th Japanese Antarctic Research Expedition (JARE-30) (T. ENDOH).

2. Recording System for Sea Ice

In order to photograph the sea ice, a video camera was mounted on board the icebreaker SHIRASE as shown in Fig. 1. The camera was located at the upper steering house with an angle of 10° downward from the horizon. The image taken by this camera was recorded on a video recorder.

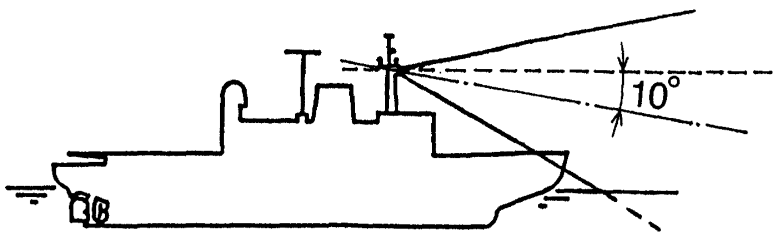

Fig. 1. System configuration for photographing sea ice. The camera was located at the upper steering house with an angle of 10° downward from the horizon.

3. Method of Analysis

After recording, these images are fed into an image processor to compute ice compactness and ice shape. The technique of analyzing sea ice images can be approached from two different methods: a two-dimensional method and a one-dimensional method. In the two-dimensional method, both ice shape and ice compactness can be obtained by analyzing predetermined square regions of sea ice images. In the one-dimensional method, ice compactness alone can be obtained by analyzing one row of pixels.

3.1. Two-dimensional method

Figure 2a shows the spatial relation between the sea surface and its projection in the image plane. Using known lengths and angles, such as camera height, distance from camera to bow and angle of depression of the camera, geometric transformation is performed. By this transformation, the inside of a square region with side 180 m is analyzed, and each image of the sea ice is transformed to an orthographic projection as shown in Figs. 2b and c. In this process, as the distance from the ship increases, the area of a pixel increases, therefore the accuracy of the area of remote pixels becomes lower. Figure 3 shows an example of a transformation from an original image to the orthographic projection. To separate the ice from the sea water, the images are binarized by suitable threshold of gray level before transform as shown in Fig. 3b. The trapezoidal region of ice-covered water in Fig. 3b is transformed to orthographic projection as shown in Fig. 3c. This method may be useful for detailed analysis of sea ice conditions. Such a transformation, however, requires much calculation, so a simpler method is also proposed.

3.2. One-dimensional method

In order to measure the sea ice compactness automatically over a long period of time, the percentage of ice to water is calculated for only one row of pixels of each image in predetermined time intervals. One advantage of this method is that data can be stored on a disk for a fairly long time, and off-line analysis can be carried out by using arbitrarily determined time intervals. Since this calculation is simple, it also permits on-line analysis of the ice compactness.

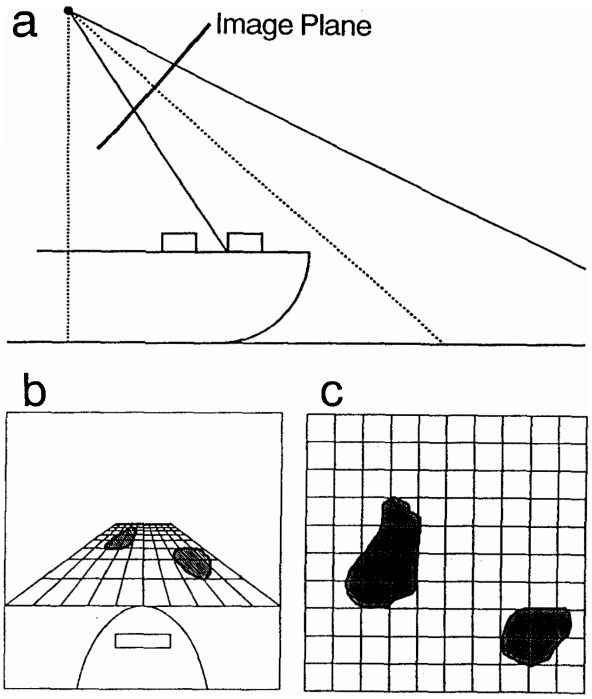

Fig. 2. Schema of geometric transformation. a) Spatial relation between the sea water and its projection in the image plane. b) Oblique projection. c) Orthographic projection transformed from trapezoid region (shown in b) on oblique projection.

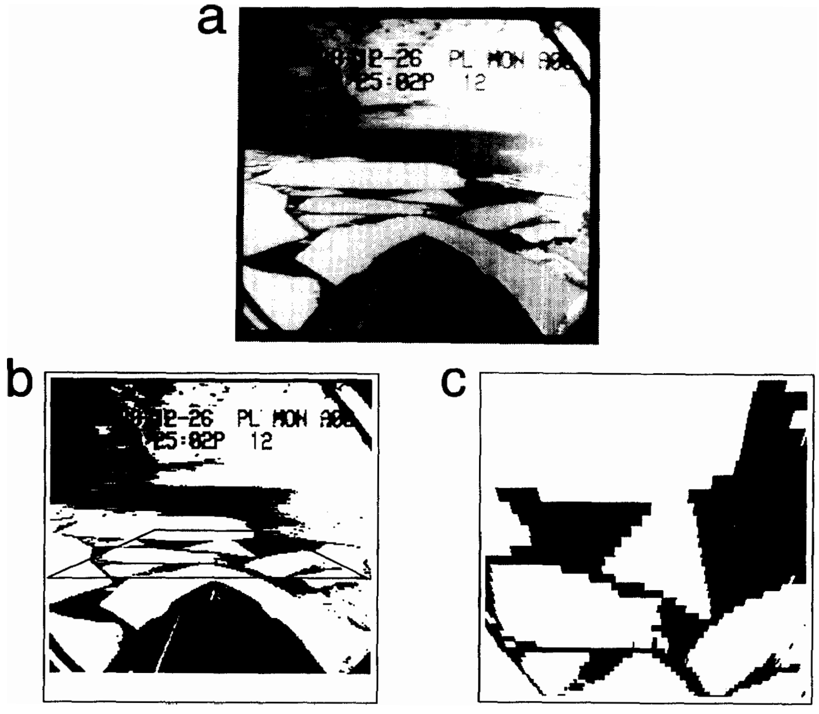

Fig. 3. Process of analysis. a) An original image. b) Binary image. c) The trapezoid region on ice-covered water was transformed to orthographic projection.

4. Experimental Results

Figure 4 shows three binary images of sea ice and corresponding transformed ones. In these figures, white parts indicate ice and black ones water, respectively. There were some cases, although the ice compactness differed little in which distributions of floe size were different. Figures 4b and c show examples of such cases: large area but small in number of ice floe covering the sea in Fig. 4b compared with Fig. 4c.

The one-dimensional method was performed in predetermined time intervals using the recorded sea ice image during navigation. The cruise track of the icebreaker SHIRASE from Breid Bay to Syowa Station is shown in Fig. 5a. Figure 5b shows changes of ice compactness in the first 12 hours. Because the vessel navigates to find the easiest passage, the ice compactness may be somewhat

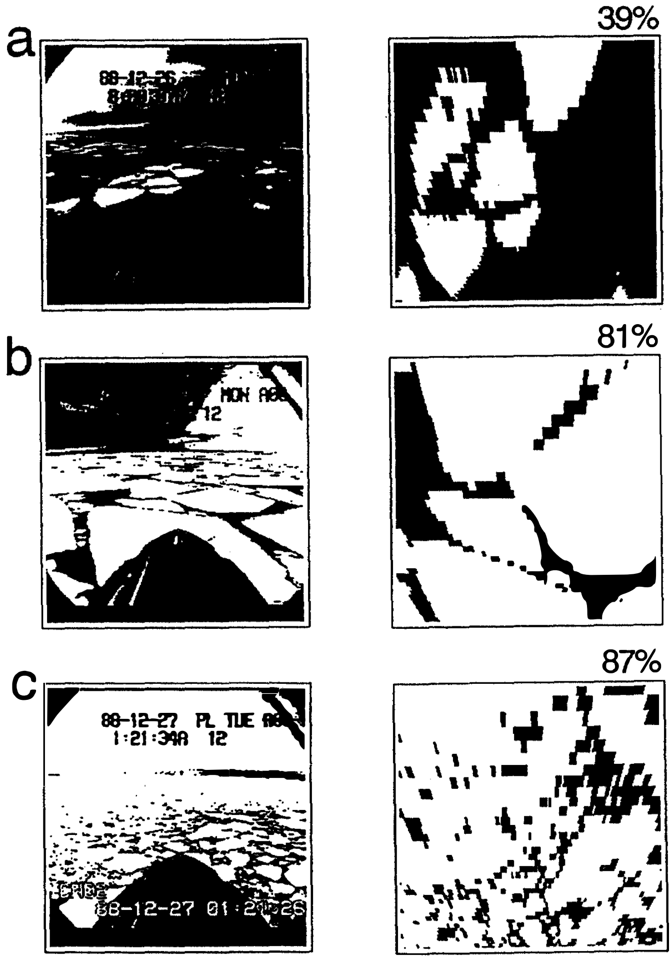

Fig. 4. Binary images of sea ice floes (left side) and corresponding transformed ones (right side). Each percent indicates the sea ice compactness. White parts indicate ice and black ones water, respectively. Although the ice compactness differs little between b and c, floe size distributions were quite different.

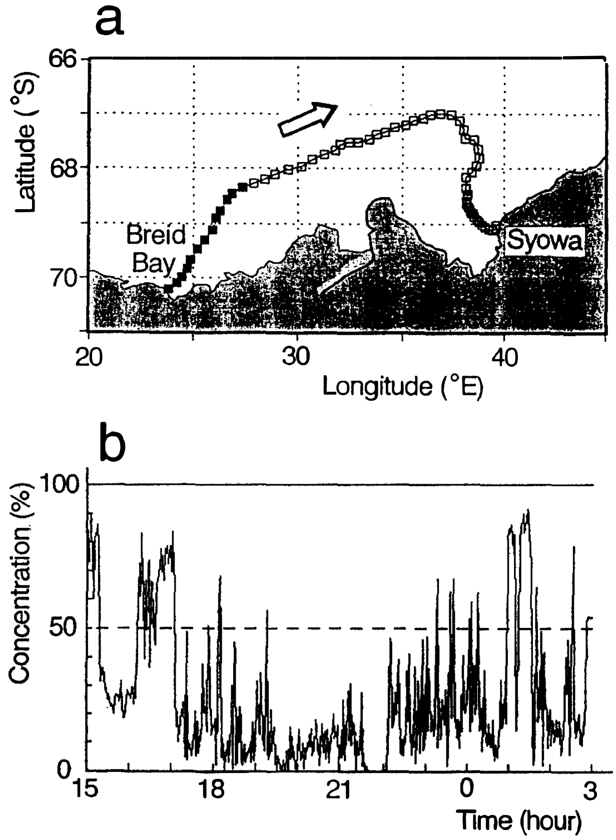

Fig. 5. One-dimensional analysis. a) Cruise track of the icebreaker SHIRASE *every hour (open square) from December 26 to December 29, 1988. b) Changes of ice compactness in the first 12 hours (solid square shown in a) was analyzed.*

biased toward lower compactness. The differences of ice compactness along the route and neighboring regions must be identified by some method, such as observation from a helicopter or remote sensing.

5. Conclusion

A personal computer aided image analyzing system for assessing sea ice condition has been proposed. The use of a computer has two advantages: (1) the shape of sea ice and the sea ice compactness are obtained quantitatively and semi-automatically. (2) Since the method of analyzing sea ice images has been programmed, if camera position parameters are changed, sea ice images can be analyzed in the same way. To transform the far position of sea ice from the ship with high accuracy is a subject for future study.

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