Annals of Glaciology 6 1985

DETECTION OF AN ICE-FORMING AREA BY RADAR AND SATELLITE

by

MASAAKI AOTA, MASAYUKI OI, MASAO ISHIKAWA AND HIROKI FUKUSHI

Sea Ice Research Laboratory,
Institute of Low Temperature Science, Hokkaido University, Mombetsu, Japan

ABSTRACT

This paper describes a method of distinguishing between pack ice and sea clutter in radar echoes, an attempt to roughly estimate the thickness of sea ice from measurement of surface temperature by air-borne infrared radiometer, and an application of thermal images from satellite data to estimate the concentration of sea ice off the Okhotsk Sea coast of Hokkaido.

INTRODUCTION

It is important both for shipping and for climatology that distribution of sea ice and its concentration and thickness are known as accurately as possible. With the completion of a sea ice radar network, it has become possible to observe the distribution of sea ice off the Okhotsk Sea coast of Hokkaido. As yet, however, little research has been done on how to discriminate between sea clutter and pack ice in radar echoes. In particular, reflections from smooth early-season ice are difficult to distinguish from rough seas. This paper describes a method of distinguishing sea clutter from pack ice by frequency analysis of the strength of radar echoes over a timed series. We describe also an attempt to estimate sea ice thickness from surface temperature by an air-borne infrared radiometer, and using a thermal image from satellite data to estimate the concentration of sea ice.

OBSERVATIONS AND DISCUSSION

Discrimination between pack ice and sea clutter

Mombetsu sea ice radar was used on 14 April 1984 to measure variations in strength of radar echoes from both pack ice and open sea. Both sea clutter and sea ice can be seen in the radar image (Figure 1); variations in intensity of radar echoes, and their power spectra, are shown in Figures 2 and 3. Frequency analysis of these time series showed that, in the power spectrum of the signal from the pack ice region, low frequency components (less than 1 Hz) prevail. Sea clutter by contrast shows characteristics of white noise when analysed, without any dominant frequency component. Thus reflections from the two kinds of surface are easily distinguishable (1).

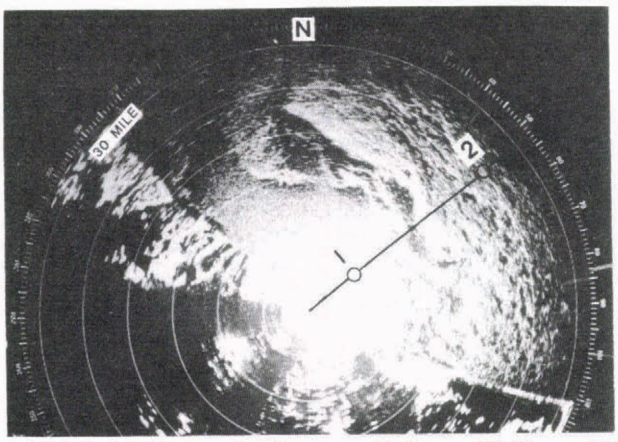

Fig.1. Radar image of Mombetsu Radar at 09:00 on 14 April 1984 (Concentric circles are 5 N.M. apart).

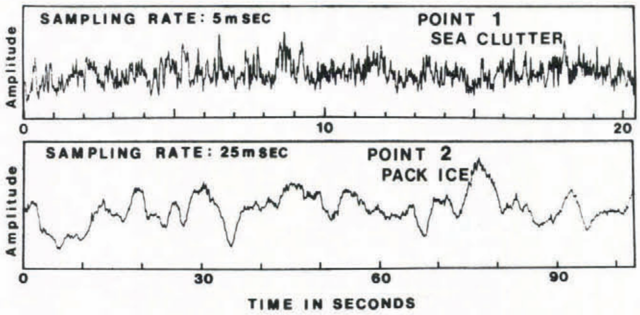

Fig.2. Time variation of reflected power at 09:000 on 14 April 1984. Point 1: 6 n. miles from Mombetsu Radar Station in the direction of 52° (Sea Clutter region). Point 2: 25 n. miles from Mombetsu Radar Station in the direction of 52° (Pack Ice Region).

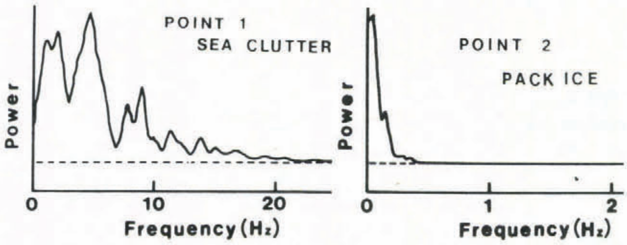

Fig.3. Power spectra. Point 1: Sea Clutter region. Point 2: Pack Ice region.

Estimation of sea ice thickness.

Variations in air temperature, ice surface temperature and ice thickness were observed by N Ishikawa and S Kobayashi (1982) at artificial pools measuring 3 x 3 m made within the frozen lake Saroma. Connected with the Okhotsk Sea, this is a salty lake. It was observed that the relation between surface temperature and ice thickness without dry snow cover was given approximately by the equation:

$$\frac{T_{is} - T_A}{T_W - T_A} = \frac{1}{1 + \alpha \cdot x}$$

where T_A, T_W and T_{is} are respectively air, water and ice surface temperatures, x is the thickness of the ice plate, and α is an empirically-determined constant. The value of α in situ based on Ishikawa's data was 0.13 (cm). The physical meaning of this constant (α) is the ratio of a heat transfer coefficient between ice surface and air to a heat conductivity coefficient of ice. However, the value α in situ involves the effects of radiations, latent heat, winds, currents as well as the ice structural characteristics.

Once the value of α has been determined in situ, the equation can be used to estimate ice thickness. It is possible to estimate a thickness of ice remotely by use of the relation expressed by the equation.

https://doi.org/10.3189/1985AoG6-1-252-253 Published online by Cambridge University Press

Application

Surface temperatures of sea ice were measured by airborne infrared radiometer on 16 February 1984, from the coast to 30 nautical miles off Mombetsu. The altitude of the flight was 10 m above sea level, with air temperature about -9.0 °C. The distribution of surface temperatures, and ice thicknesses estimated by use of the equation (with α 0.13 cm) are shown in Figure 4. The estimates were in relatively good agreement with the visual inspection from the helicopter.

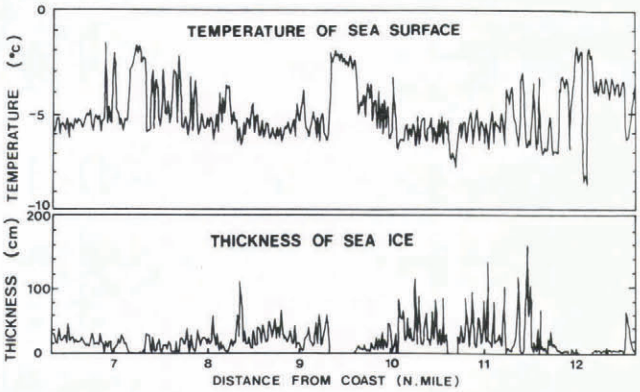

Fig.4. Surface temperature of sea ice off Mombetsu (from 6 to 13 n. miles) at 14:00 ~ 14:30 on 16 Feb. 1984 with IR radiometer and estimated thickness.

Estimation of sea ice concentration

Figure 5 is a thermal image obtained from satellite NOAA-8 (geographical resolution : 3.7 km) on 10 March 1984. Open water appears darkest, cold regions appear bright. The surface temperatures were grouped into five classes. Where there are open water regions within pack ice, Figure 5 shows average temperature values. Thus temperature distribution in the figure is related to sea ice concentration. Figure 6 is a visual image from LANDSAT 4 (geographical resolution : 80 m), covering the same area as Figure 5 at almost the same time, from which sea ice concentration may be calculated directly. Figure 7 shows the relationship between surface temperatures calculated from Figure 5, and ice concentrations calculated from Figure 6. As Figure 7 shows, temperature distributions obtained from the NOAA image are a good indicator of sea ice concentrations.

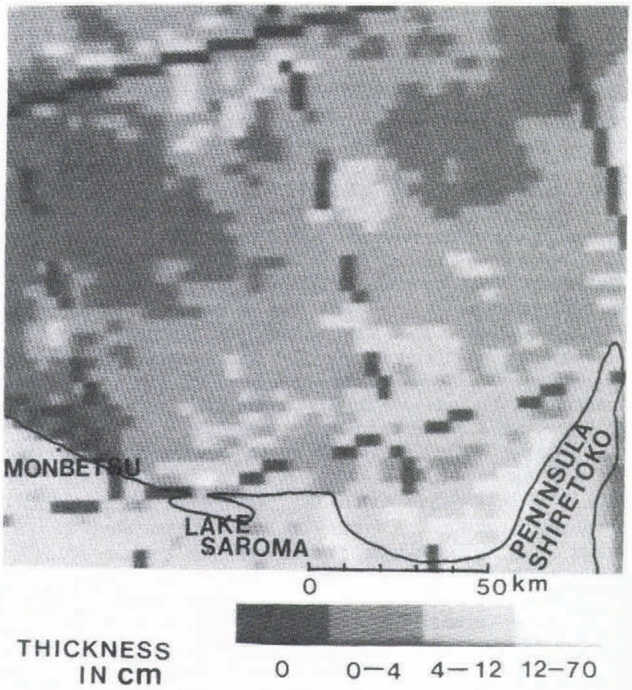

Fig.5. Distribution of thickness estimated from IR imagery of NOAA-8, 10 March 1984.

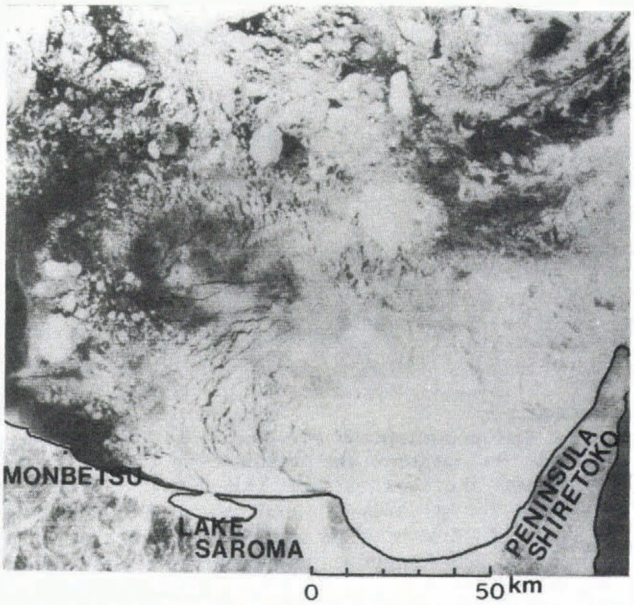

Fig.6. Visual imagery of Landsat, 10 March 1984.

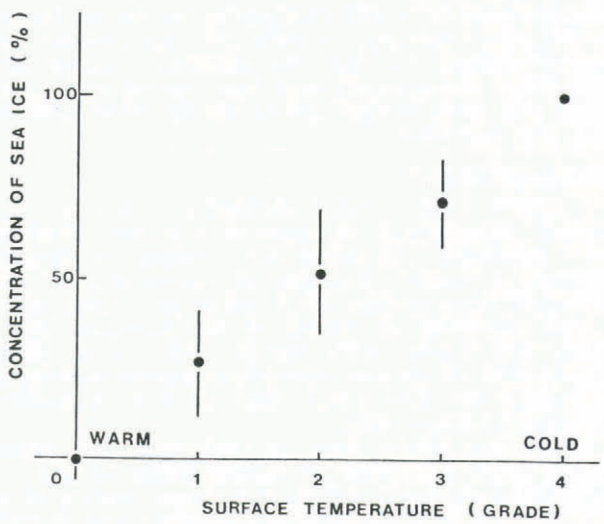

Fig.7. Relation between the surface temperature and concentration of sea ice (lines on both ends show standard deviation).

REFERENCE

Ishikawa N, Kobayashi S 1982 [Short-term variations in heat budget with the growth of sea ice]. *Teion-Kagaku: Low Temperature Science* A 41: 179-189 (in Japanese)