ARCTIC ICE MEASUREMENTS WITH MICROWAVE RADIOMETERS

Dr. Per Gloersen

We have continued our program of airborne passive microwave experiments in support of the upcoming missions to be flown on the Nimbus E and F and EOS satellites. I would like to report some of the highlights of our most recent expedition with the NASA remote-sensing aircraft to the Arctic polar region. The mission took place during March 1971. The flights were in conjunction with the Arctic Ice Dynamics Joint Experiment (AIDJEX), which is a cooperative interagency effort involving several U.S. and Canadian organizations.

The AIDJEX group established and operated a base camp, Camp 200, on the Arctic polar ice canopy at a location approximately 74° N and 131° W, which is just inside the limits of the permanent polar ice pack off Banks Island. They were, therefore, in an excellent position to supply us with detailed surface truth information in a limited region of the polar ice canopy that could be used to interpret the microwave signatures of the sea ice that we had obtained at seven different wavelengths while flying over Camp 200.

Figure 1 is a map of the region in which these activities took place. This map, which covers an area of about 76 by 95 km (40 by 50 n. m.), was produced from data obtained with the 1.55-cm mapping microwave radiometer. What you see is an enormous multiyear ice floe about 48 by 29 km (25 by 15 n. m.) in extent surrounded by first-year ice. Camp 200 was located at about 74°07'N, 131°24'W on the edge of this ice floe. It is interesting to note that although the members of the expedition knew the camp was located near the edge of the multiyear ice floe, they had no idea of the vastness of this particular floe until this image was formed after the expedition. This image is, of course, a false color representation of the radiometric brightness temperatures of the ice. The temperature scale in kelvins appears on the right of the figure.

The experiment I am describing represents a first. It is the first time that Arctic ice data have been obtained simultaneously on the surface with conventional instrumentation and remotely with microwave and infrared radiometers, photography, and a laser geodolite.

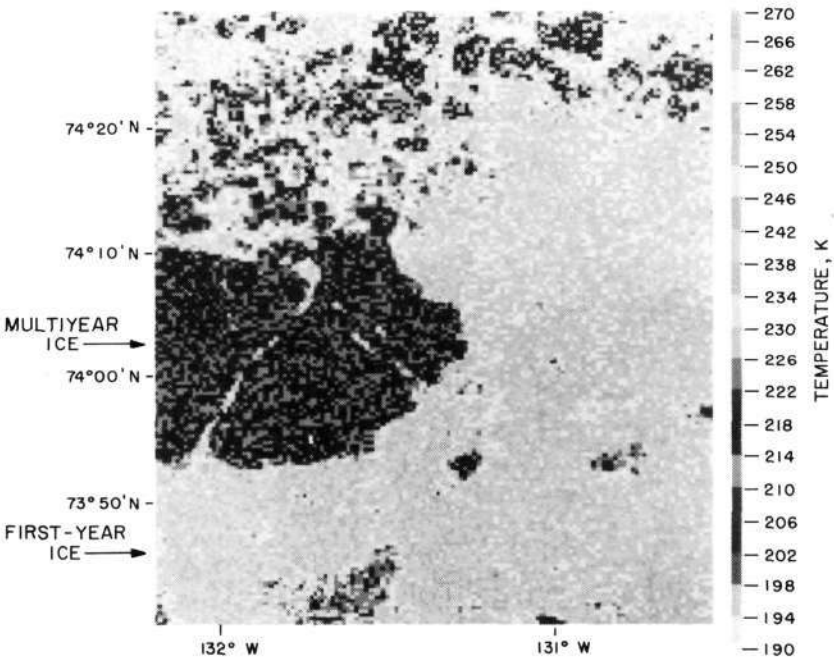

Figure 1–Passive microwave image of Arctic sea ice ($\lambda = 1.55$ cm) taken on a clear day from a NASA aircraft, March 15, 1971.

The mosaic in Figure 1 was produced by flying five equally spaced parallel tracks at an altitude of 11 km and using a computer to arrange the digital radiometer and positional data in map format, much in the same way as the microwave data to be obtained from the Nimbus E and F radiometers will be formated.

According to the AIDJEX surface truth data, the temperature at Camp 200 was 256 K, which was within 2 K of the value recorded by the onboard infrared radiometer. Another observation of the ground crew was that there were no substantial differences in the surface temperatures of the multiyear ice and the first-year ice. This again was substantiated by the onboard infrared radiometer. Thus, in this mosaic, the radiometric temperature differences are due almost entirely to emissivity differences between the two kinds of sea ice.

I would like now to show you some of the multichannel data obtained from a low-altitude pass over this area and on the return leg to Eielson Air Force Base.

Our pass started at about 74°20′N, 131°W in a southwesterly direction, passed over the northeastern boundary of the multiyear ice floe, over the region of multiple refrozen leads and on across the southern boundary of the multiyear floe again to first-year ice.

Figure 2 shows the response of seven different microwave radiometers to the two kinds of sea ice near the AIDJEX camp. We can see clearly the boundaries of the large ice floe at the highest frequencies; the multiple refrozen leads appear as spikes between the boundaries of the ice floe.

With the exception of the 94-GHz radiometer, we have confidence in the sensitivity shown at the left of each record. The radiometric temperature of the first-year ice is approximately 250 K in all cases. Thus, as we had noted from earlier studies, the emissivity difference between multiyear and first-year ice increases with frequency up to about 38 GHz. We can just begin to see this contrast at 10.69 GHz. If our 4.99-GHz radiometer had been less noisy, it is conceivable that the phenomenon might have been observable at that frequency also.

In conclusion, since we were fortunate in having ground truth available to us from the ice canopy, we can now ascertain the relationship between the various microwave radiometric temperatures and ice type.

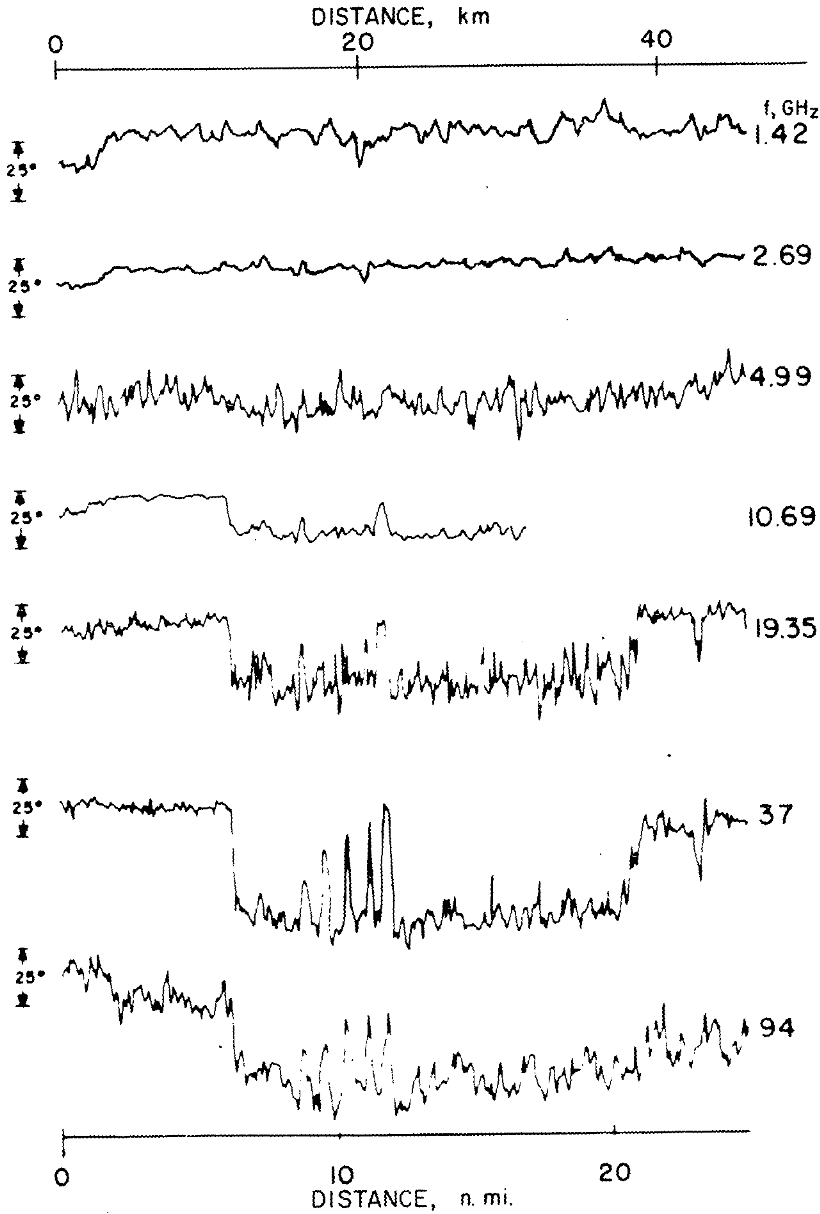

Figure 2–Multifrequency view of large multiyear ice floe.

CHAIRMAN:

Are there any questions?

MEMBER OF THE AUDIENCE:

What happens on a cloudy day?

DR. GLOERSEN:

I can show you the results of such conditions in Figure 3. This was taken on the following day when there was a complete undercast over the AIDJEX campsite. There seems to be a net 8-K upward shift of temperatures, both over the multiyear ice and the first-year ice, so there is some slight effect. As you can see, the features still appear the same.

MEMBER OF THE AUDIENCE:

What are the spikes that appear in Figure 2?

DR. GLOERSEN:

The large spikes between the ice floe boundaries are the refrozen leads in the large ice floe. The cracks are filled with first-year ice. They did not show at the high altitude in that much detail. Only about two of them appeared at high altitude, but these data were obtained at low altitude.

MEMBER OF THE AUDIENCE:

How do you account for the difference in emissivities?

DR. GLOERSEN:

At this point, we have only a qualitative idea. We think that it is strongly connected with skin depth. In first-year ice, the salinity of the ice is a function of its age. Brand new ice is highly saline, about half the salinity of ocean water, and the salinity decreases – I hestitate to say exponentially, but let us say expotentially – with age. The saline ice is a lossy substance, and it has a rather high emissivity. The skin depth in multiyear ice, which is practically pure water ice, is rather large in terms of wavelengths. Therefore, the opportunity for volume scattering exists; and when there is good volume scattering, you are really looking at the sky, which has a very low brightness temperature, because you are looking in a diffused reflector. That is one way of accounting for the difference. We are exploring it actively in more detail.

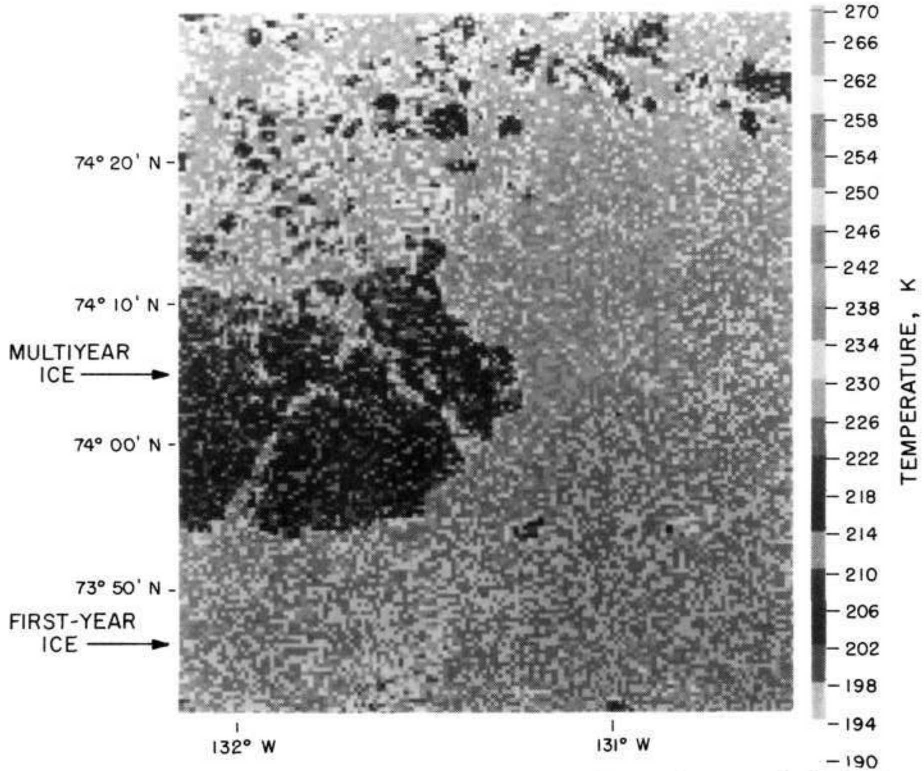

Figure 3–Passive microwave image of Arctic sea ice ($\lambda = 1.55$ cm) taken on a cloudy day from a NASA aircraft, March 16, 1971.