NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technical Memorandum 33-751

The JPL Imaging Radar Experiment in GATE

A Preliminary Report

Charles Elachi

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JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
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PREFACE

The work described in this report was performed by the Space Sciences Division of the Jet Propulsion Laboratory.

ACKNOWLEDGMENT

The JPL imaging radar experiment in GATE was a team effort. Many people contributed to its success, especially Messrs. E. Caro, E. McMillan, W. Skotnicki, J. Granger, R. Blakely, W. E. Brown, Jr., A. Laderman, D. Harrison, T. Bicknell, and G. Warner from the Jet Propulsion Laboratory. We also acknowledge the excellent support provided to us by the Airborne Science Office, Ames Research Center, especially Mr. E. Petersen and the crew of the CV-990 aircraft.

CONTENTS

ABSTRACT

This report summarizes the type of data that was taken with the JPL imaging radar during the Global Atmospheric Research Program (GARP) Atlantic Tropical Experiment (GATE) mission and gives a representative sample of the data.

I. INTRODUCTION

This report is a brief summary of the objectives and accomplishments of the JPL imaging radar experiment during GATE (the Global Atmospheric Research Program (GARP) Atlantic Tropical Experiment), which was conducted in the summer of 1974.

A brief explanation is given of the instrumentation used in the experiment and includes a small sample of the data. This data is now available to the scientists who participated in GATE and to the scientific community.

II. OBJECTIVES AND ACCOMPLISHMENTS

The objective of the imaging radar experiment was to provide two-dimensional radar imagery of the ocean surface in support of the oceanographic program in GATE. The radar waves are backscattered by the small-scale roughness (capillary or small gravity waves) on the surface. Thus the radar image is a two-dimensional presentation of the change in the surface roughness or slope. The modulation of the surface roughness can result from the presence of swells, internal waves, currents, fronts, rainfall, slicks, local wind change, and others. The modulation of the slope results mainly from the presence of large waves.

The JPL imaging radar (right-side looking) was mounted on the NASA CV-990 aircraft. Thus, the radar data collected corresponds to a continuous swath, about 10 km wide, all along the flight path. Data was collected on almost every flight undertaken during Phase 3 and on a number of flights undertaken during Phases 1 and 2. Most of the data was taken with the L-band (25-cm) radar system, and some data was taken with the VHF and X-band systems.

All the L-band data has been processed on the JPL optical correlator and is available on glossy 70-mm films.

III. COHERENT IMAGING RADAR PRINCIPLE

Basically, a synthetic aperture imaging radar consists of a coherent radar on a platform moving with a uniform velocity, whose antenna becomes a new element of a synthetic antenna array with each successive transmission.

The transfer functions of the radar subsystems are linear such that the amplitude and the phase of the returned echo is preserved; therefore, coherent processing of the successive echoes can be conducted in a data-processing system that can reconstruct the original scene and generate high-resolution imagery (Fig. 1a). The basic approach is similar to the one used in holography. The attractive feature about the coherent radar system is that an exact replica of the amplitude and phase of the reflected echo is recorded and transmitted to the processing center where large computers are available, and the mission can be "reflown" many times to focus on some specific parameters. Details on the synthetic aperture radar concept can be found in the literature (Refs. 1-4).

The coherent imaging radar provides its own illumination and operates in a microwave region in which clouds are transparent. Therefore, it is an all-time, all-weather remote sensor. It provides two-dimensional, high-resolution (a few tens of meters) imagery of the ocean surface. The image brightness is proportional to the radar backscatter cross-section which, in turn, is proportional to the surface roughness.

IV. EXPERIMENT DESCRIPTION

A. Flight Equipment

The L-band radar was developed by JPL and was installed on the NASA-Ames CV-990. The parameters of the radar system are given in Table 1. It is worth noting that the JPL imaging radar development has been directed toward eventual spacecraft use, either for Earth or Venus observations. Consequently, the wavelength and observing geometry are different from most of the imaging radars developed for other purposes. Aircraft radars that operate at frequencies of 10 GHz or higher and with grazing angles of incidence are common. The geometry used during our observations emphasizes the near-vertical viewing and is illustrated in Fig. 1b. The imagery output is usually a continuous strip with a swath width of 8 to 12 km. The first return or nadir echo appears on most of our imagery, usually as a bright line. In most cases we have not converted the radar image coordinates to orthographic mapping coordinates. Hence, there is image distortion particularly near nadir. Another characteristic of the imagery is that low-contrast effects disappear at large incident angles because the signal level drops below the system noise level. This is primarily a result of the range loss factor and the radar receiver gain setting and, secondarily, a property of the surface backscatter.

B. Ground Data Processing

An exact replica of the radar echo (amplitude and phase) is optically recorded in real-time on a film called the signal film. This data is later processed on an optical correlator that generates the synthetic aperture and provides a two-dimensional image. Details on coherent optical processing can be found in the literature (Refs. 2-5).

Synthetic aperture radar systems have the property of producing a speckle effect in the generated image similar to the effect seen with laser illumination. This speckle effect is reduced by applying multiple-look processing, i.e., averaging several images of the same area. For the L-band imagery presented here, the number of looks is five, and the resulting image resolution is about 15 m.

V. FLIGHTS AND DATA AVAILABLE

Imaging radar data was collected during the following flights undertaken by the NASA CV-990 during all three phases of the GATE mission. The 6-digit flight code number corresponds to the year (2 digits), month (2 digits) and day (2 digits) of the flight in that order. A brief description of the flight pattern and data collected is also included as well as some examples.

740624

Transfer flight from San Juan to Dakar via Cape Verde Islands. Radar imagery taken during part of this flight showed very short wavelength swells all across the Atlantic.

740628, GATE Mission 179-2, Flight Type 1A

The swell pattern was observed from four different directions (box pattern) verifying that the radar can observe swell patterns regardless of their direction relative to the line of flight (Fig. 2).

740630, GATE Mission 181-3, Flight Type 7B1

Very complex patterns of surface roughness were observed (Figs. 3, 4).

740702, GATE Mission 183-2, Flight Type 7B2

Large swells and surface slicks. Sharp front of roughness change was observed (Figs. 5, 6). In Fig. 6 the patterns observed could be generated by internal waves or fronts.

740709, GATE Mission 190-1, Flight Type 1A

Large slicks and sharp fronts observed (Figs. 7, 8). The slicks in Fig. 7 are probably surface slicks generated by the local wind. The front in Fig. 8 could be a result of a sharp change in the surface wind, which would give a sharp change in the surface roughness. It could also be caused by rainfall.

740717, GATE Mission 198-1, Flight Type 7B

Transfer flight from Dakar to Mallorca. Slicks and ship wake observed in the Mediterranean Sea.

740725, GATE Mission 206, Flight Type 7B

Transfer flight from Mallorca to Dakar.

740729, GATE Mission 210-1, Flight Type 1A

Linear and complicated slicks were observed (Figs. 9-12).

740814, GATE Mission 226-5, Flight Type 7B1

No waves observed. Nothing of special interest.

740818, Transfer Flight, Dakar to Mallorca

740828, Transfer Flight, Mallorca to Dakar

740830, GATE Mission 242-2, Flight Type 7C1

Radar imagery shows long swells and large areas of smooth water (Fig. 13).

740901, GATE Mission 244-3, Flight Type 7C2

Waves and wind slicks observed (Figs. 14-16).

740902, GATE Mission 245-1, Flight Type 1A

Nothing of any interest was observed.

740904, GATE Mission 247, Flight Type 7B1

Flight over the desert.

740905-1, GATE Mission 248-4, Flight Type 1A2

Many linear slicks, most probably wind slicks were observed (Figs. 17, 18). These slicks had an amazing periodicity and were observed during two passes of more than one hour apart. In Fig. 18 the distance between successive smooth areas is about 2.5 km.

740907-1, GATE Mission 250-1A, Flight Type 5B1, 7B1

Nothing of any interest was observed.

740908, GATE Mission 251-2, Flight Type 1A

Swells barely observed. Some wind slicks.

740910, GATE Mission 253-2B, Flight Type 7B1, 7C2

Wave pattern and extensive wind slicks in some areas (Fig. 19).

740912, GATE Mission 255-2, Flight Type 1-2

Clear wave patterns, some wind slicks.

740913, GATE Mission 256-1, Flight Type 2B

Ocean swells observed. Coastal waves.

740924, Transfer Flight, Dakar to Amsterdam

Obtained ocean swell patterns all along the eastern Atlantic (Fig. 20).

740928, Transfer Flight, Amsterdam to USA

Obtained ocean swell pattern all across the northern Atlantic.

SUMMARY

The data taken by the JPL imaging radar during GATE is available on 70-mm glossy films. The scientific analysis of this data is being conducted simultaneously with data taken during other flight experiments undertaken as part of our radar oceanography program. The results will be published in the open literature.

REFERENCES

1. Rihaczek, A. W., Principles of High Resolution Radar, McGraw Hill, New York, N.Y., 1969.

2. Brown, W. H., and Porcello, L., An Introduction to Synthetic Aperture Radar, IEEE Spectrum, 52-60, 1969.

3. Harger, R. D., Synthetic Aperture Radar Systems, Academic Press, New York, N. Y., 1970.

4. Goodman, J. W., Introduction to Fourier Optics, McGraw Hill, San Francisco, Ca., 1968.

5. Lugt, A. V., "Coherent Optical Processing," Proc. IEEE, Vol. 62, pp. 1300-1319, 1974.

Table 1. Radar parameters

Transmitted peak power	7 kW
Frequency (wavelength)	1215 MHz (25 cm)
Pulse repetition frequency	1 kHz at platform velocity v = 250 m/s
Pulsewidth	1.25 μs
Bandwidth	10 MHz
Antenna	Phased array 75 cm long, 25 cm wide, 5 cm thick for each polarization
Polarization	Horizontal - Horizontal
Beam	Range beamwidth 90 deg centered 45 deg off vertical
	Azimuth beamwidth 18 deg centered on zero doppler
Recorder	Goodyear 102, dual channel, 5-in. film
Areal resolution	20-m range (45 deg), 10 m along track

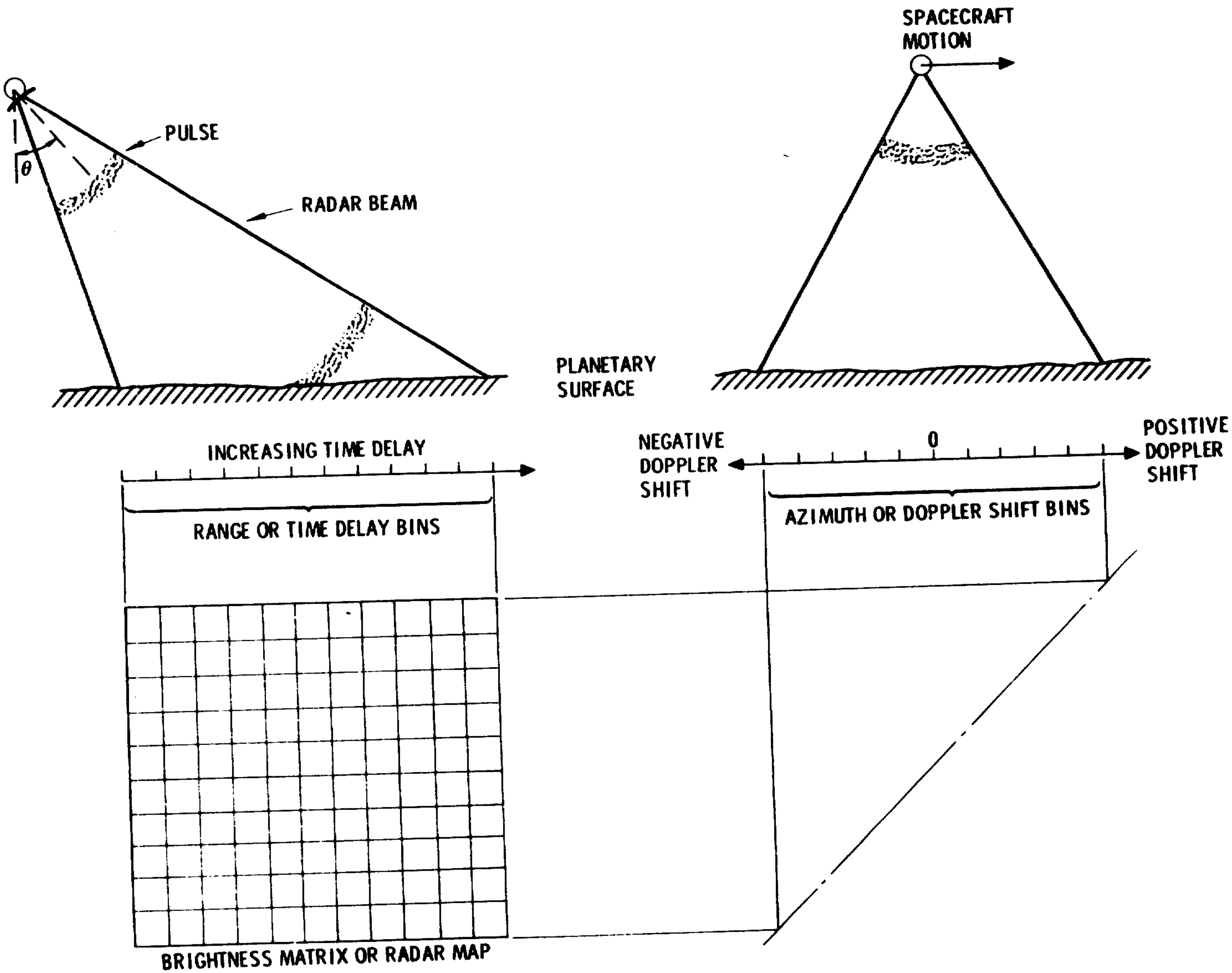

Fig. 1a. Coherent radar imaging principle: range and azimuth resolution. Range resolution is obtained from the time delay information. Azimuth resolution is obtained from the doppler information. Simultaneous time-delay and doppler processing provides a two-dimensional image of the surface

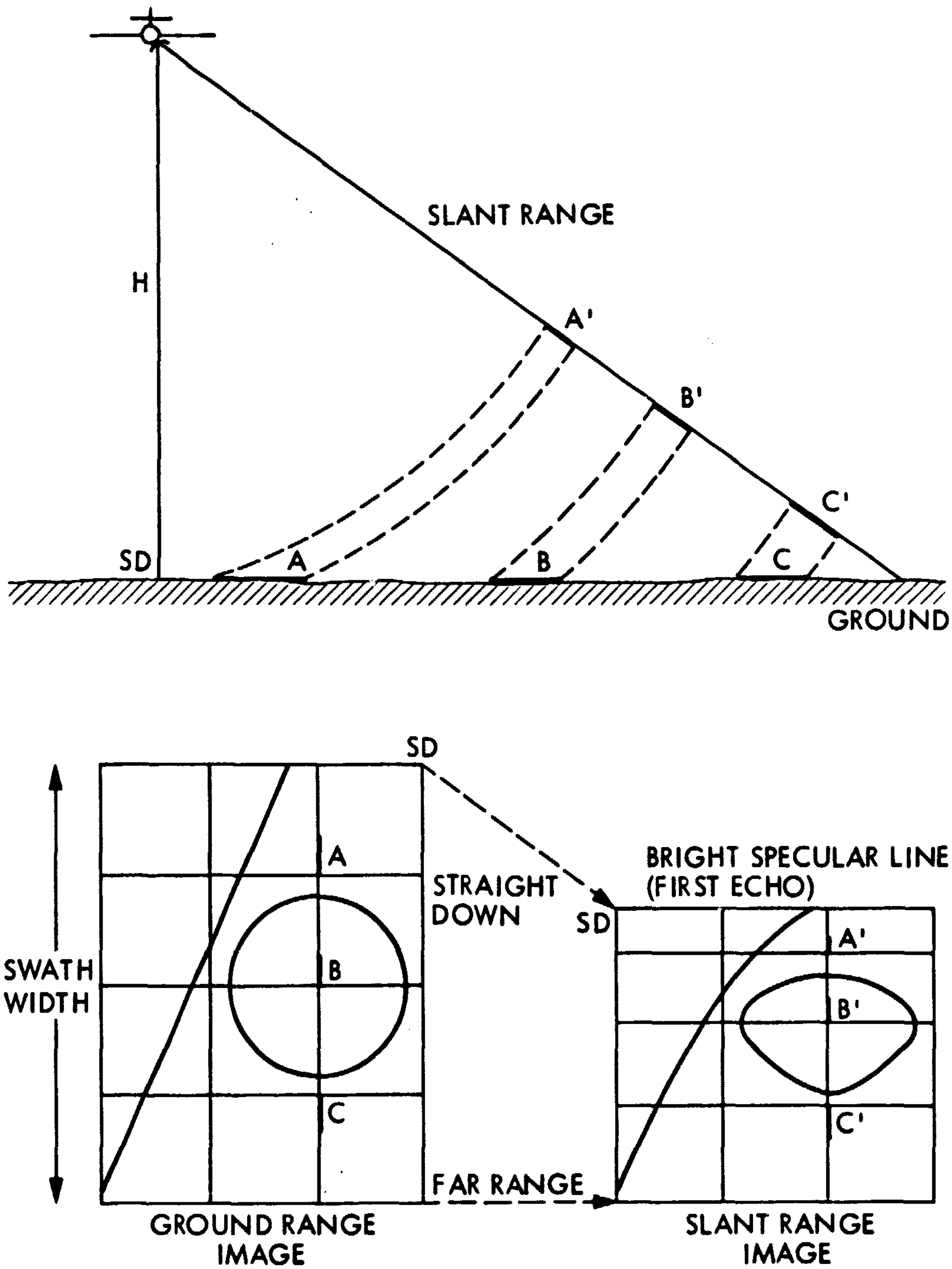

Fig. 1b. Geometric distortion inherent to the radar geometry

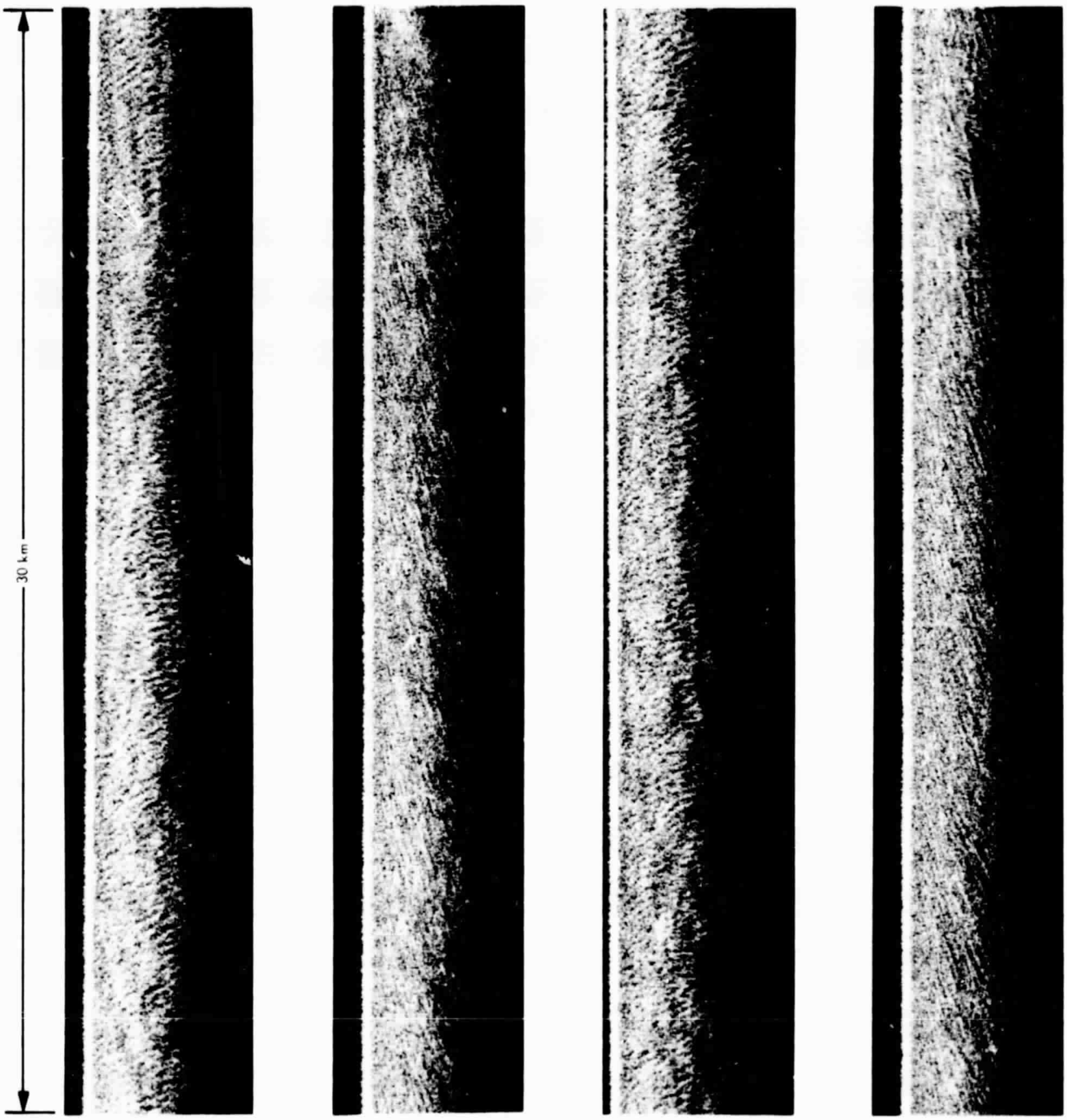

Fig. 2. Image of waves taken from four different sides of a square pattern

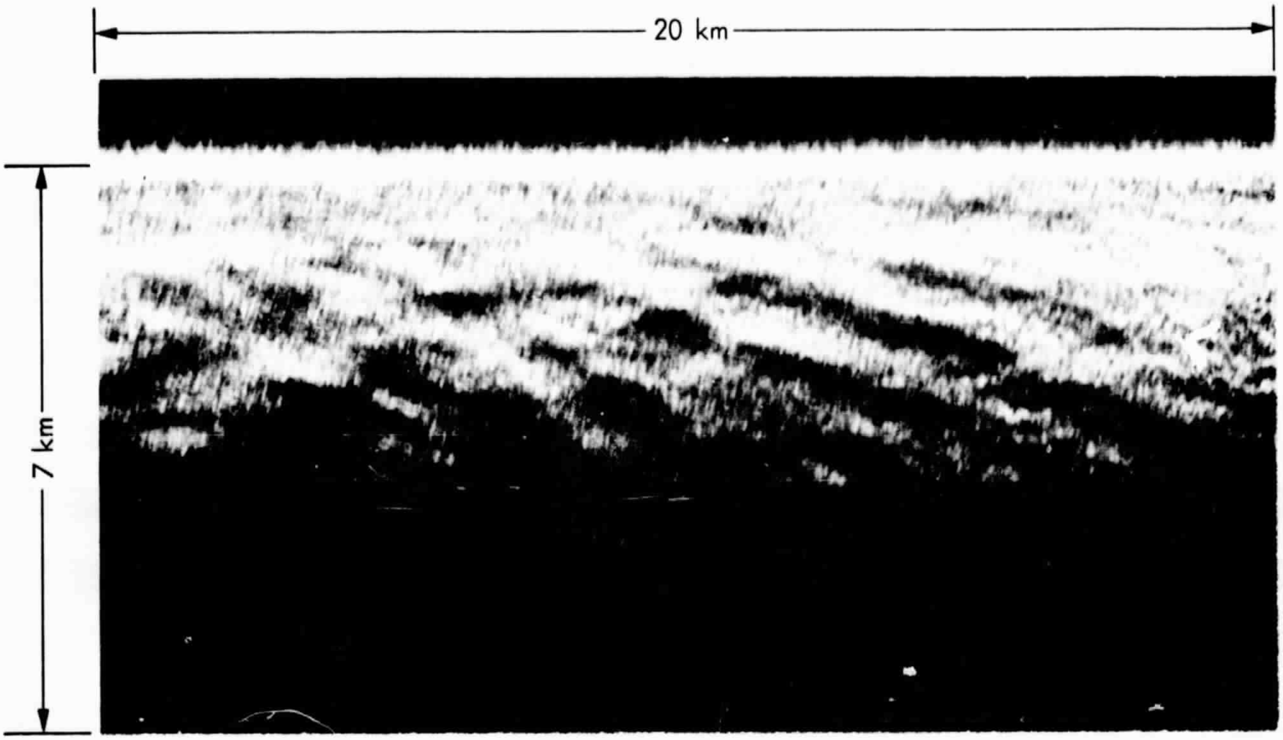

Fig. 3. Linear pattern of surface roughness

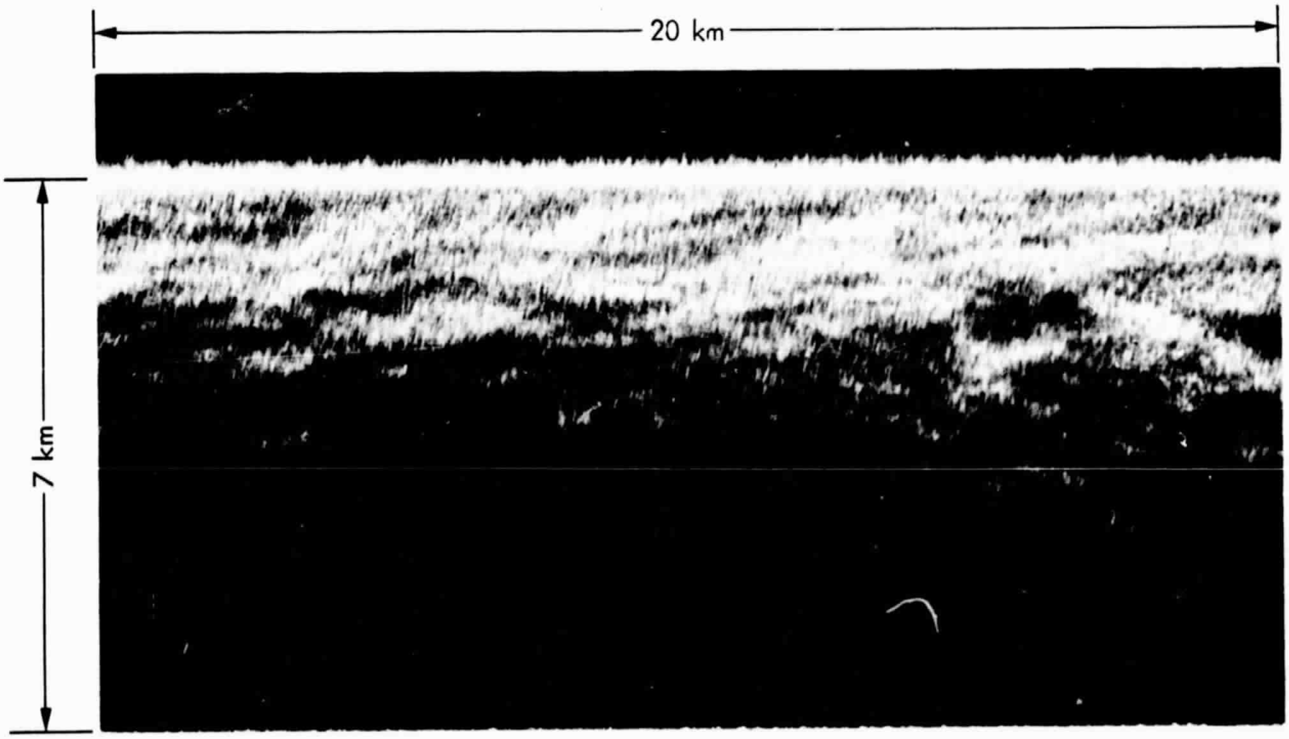

Fig. 4. Patterns of surface roughness

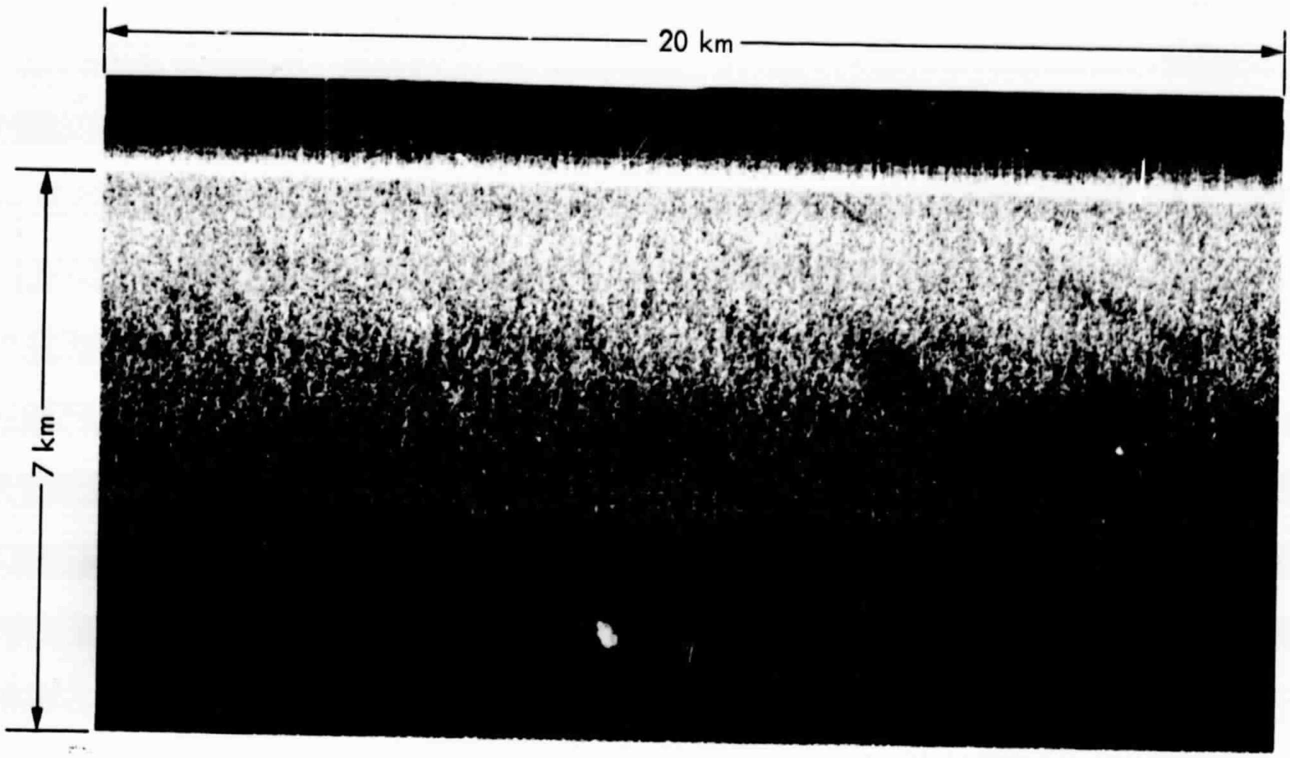

Fig. 5. Ocean swells

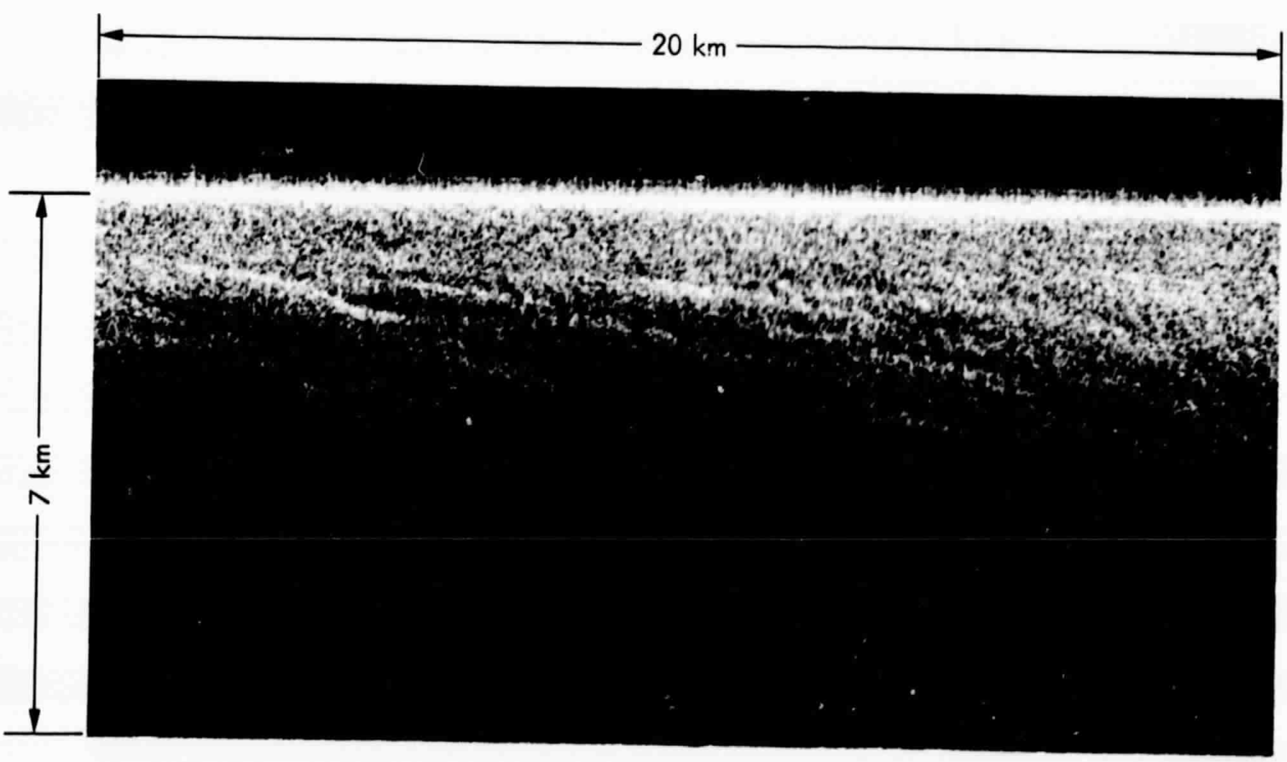

Fig. 6. Swells and linear slicks

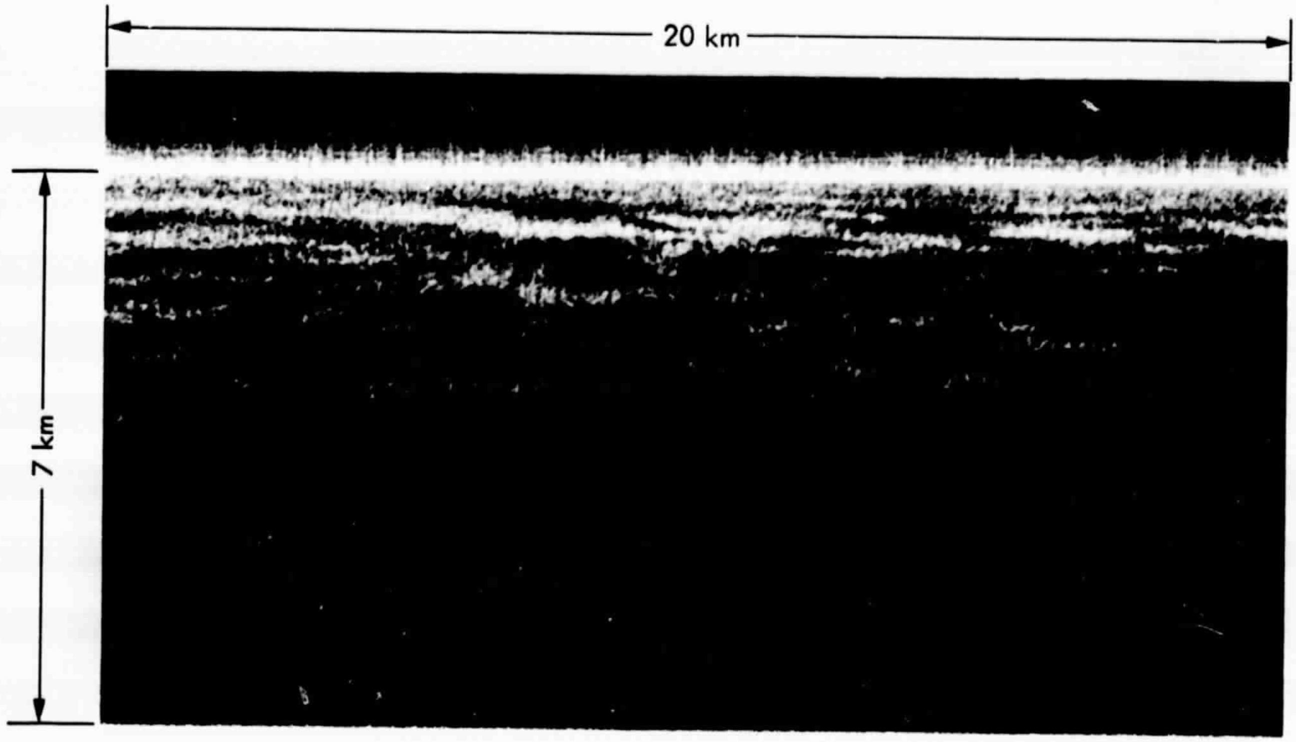

Fig. 7. Surface slicks

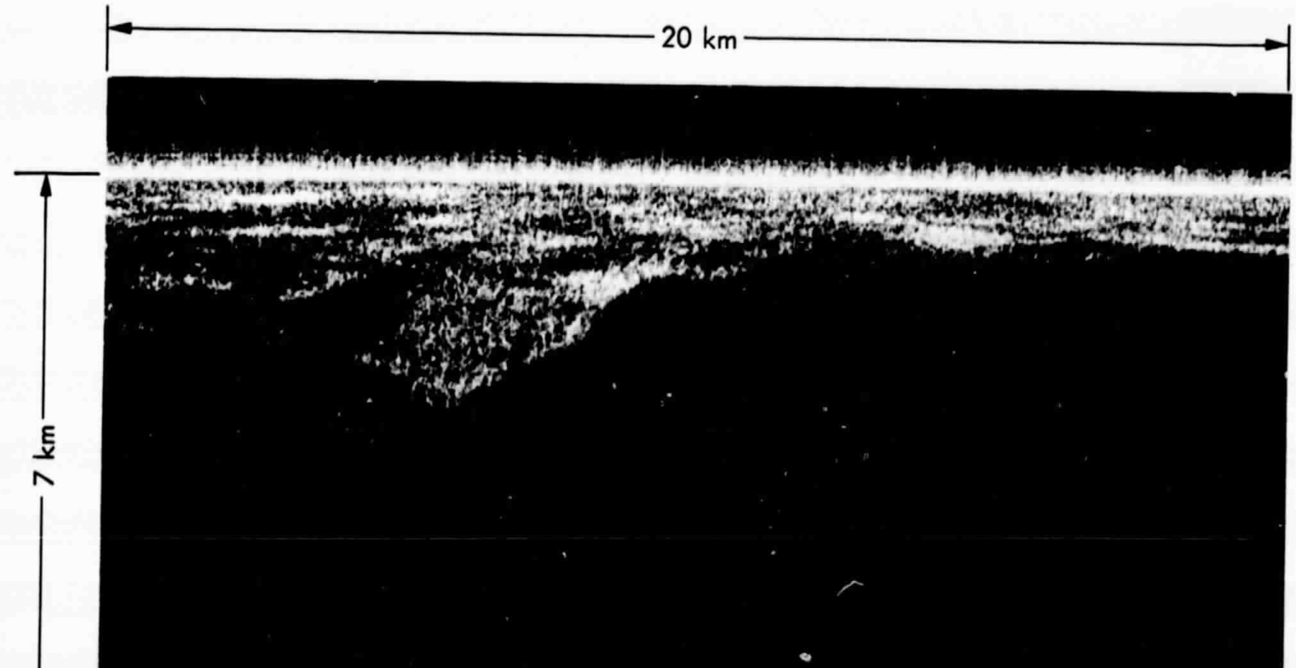

Fig. 8. Roughness front

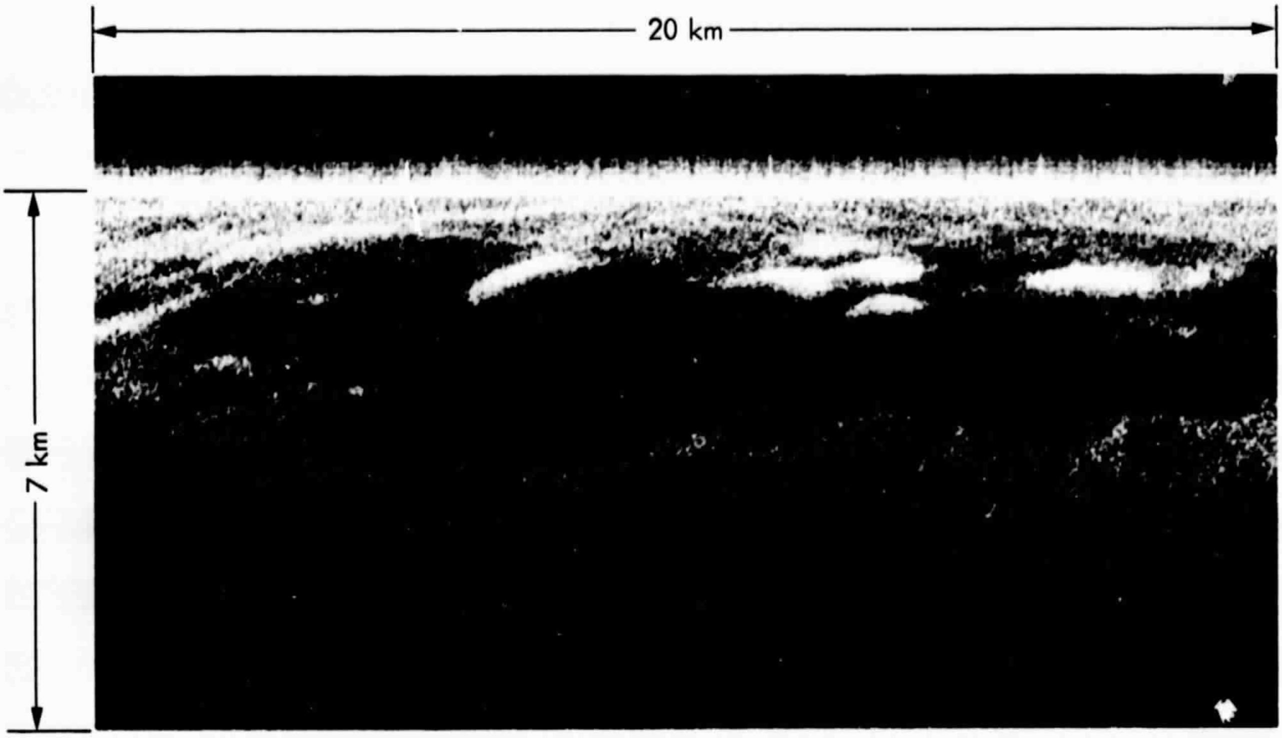

Fig. 9. Local areas of strong and weak roughness

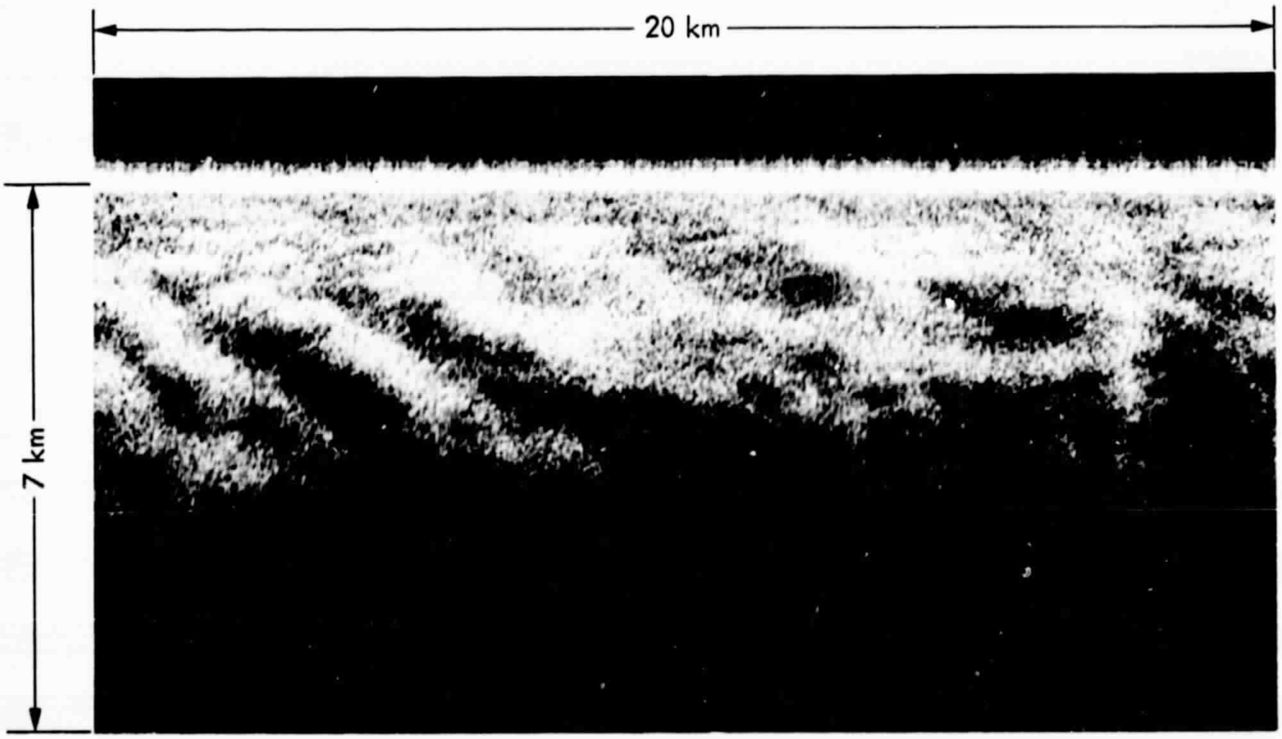

Fig. 10. Linear areas of different roughness which seem to be wind slicks

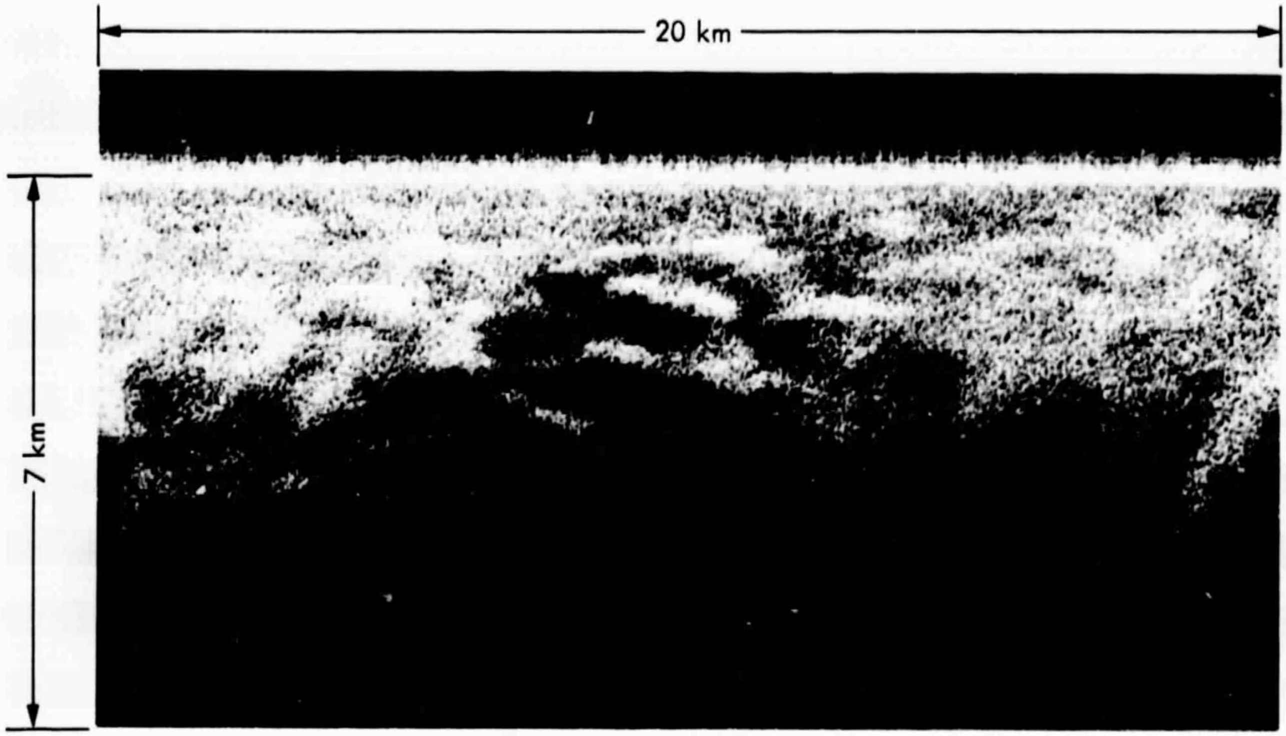

Fig. 11. Patches of smooth and rough water

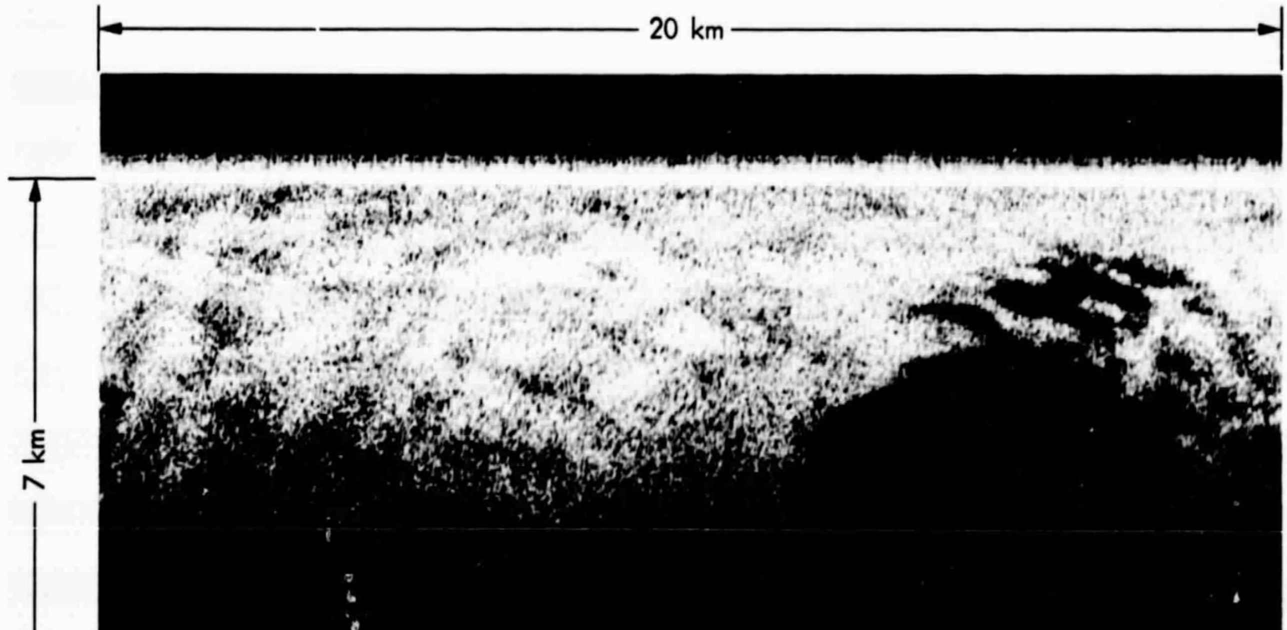

Fig. 12. Local area of smooth water

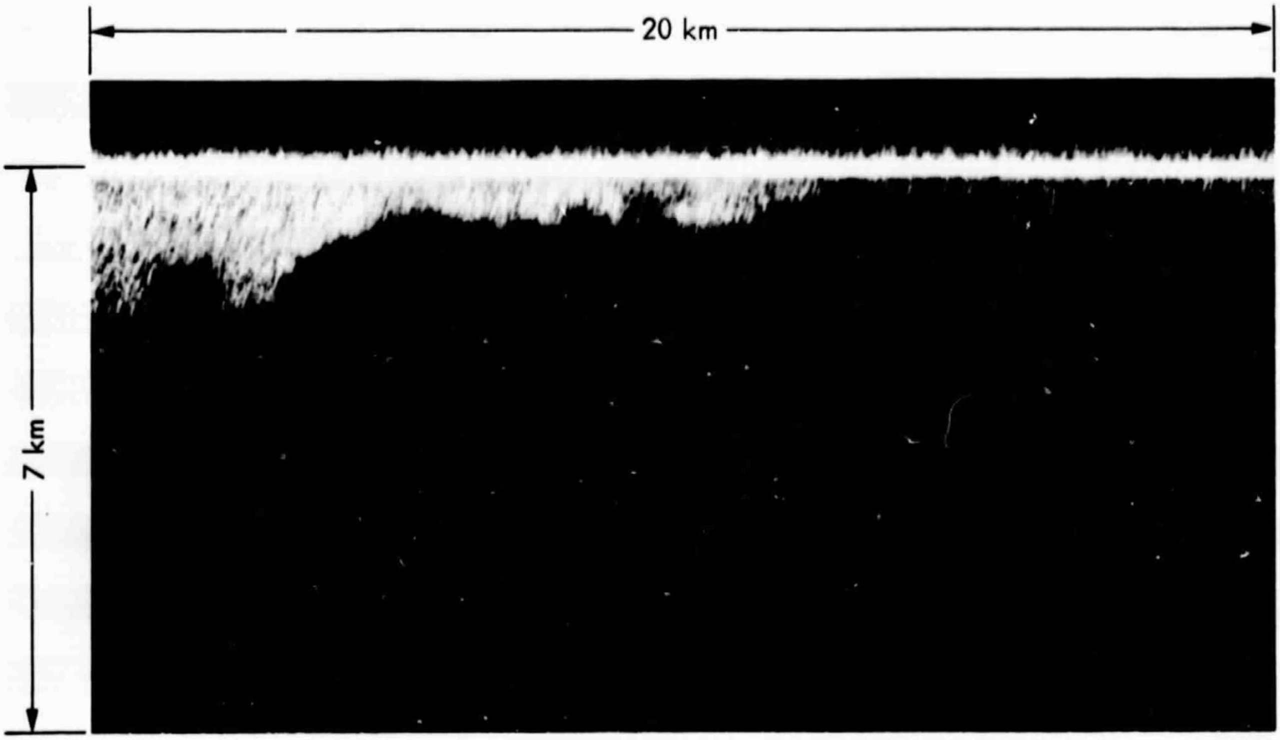

Fig. 13. Sharp roughness front

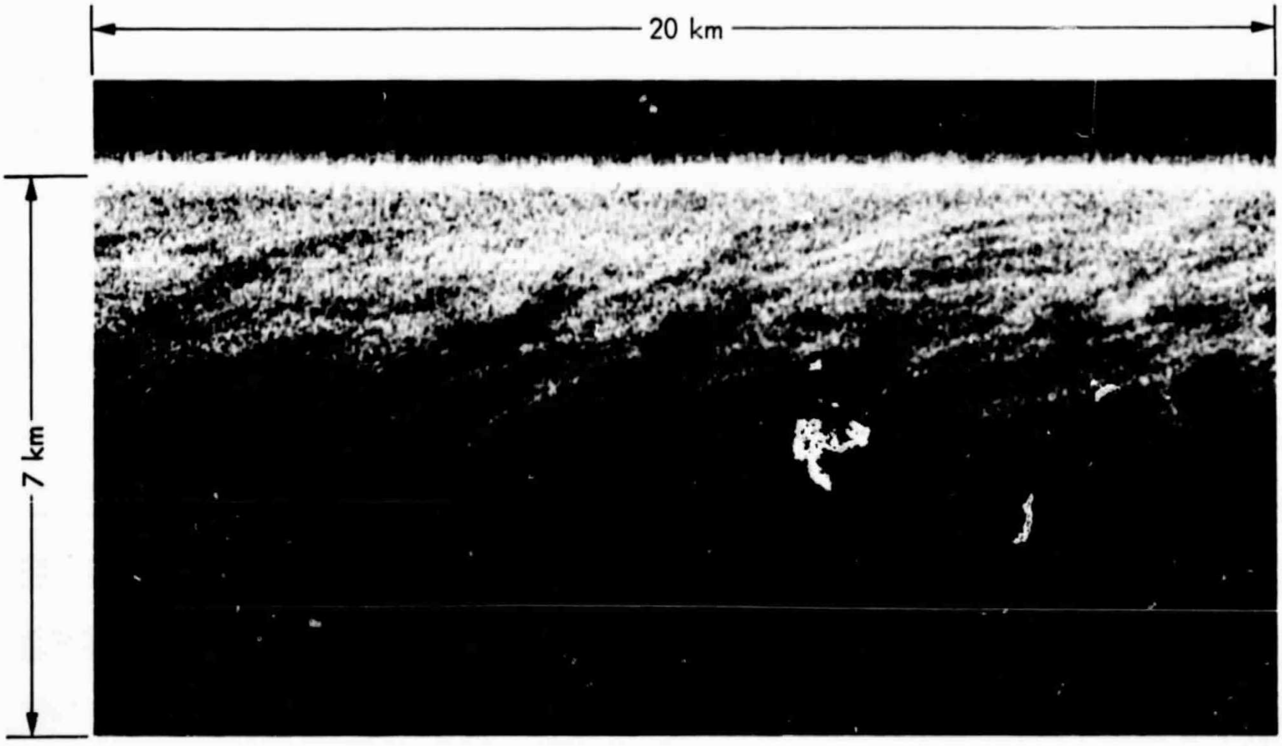

Fig. 14. Linear slicks

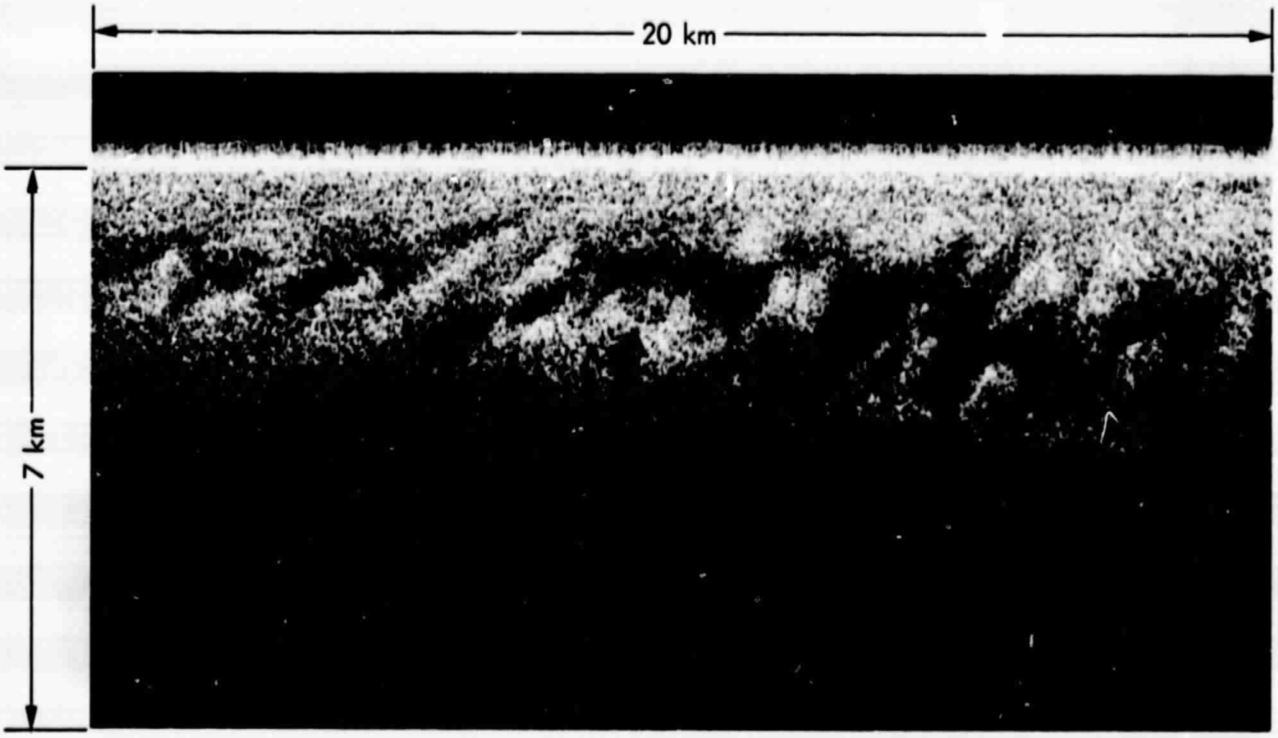

Fig. 15. Swells and surface features which might be the result of surface wind

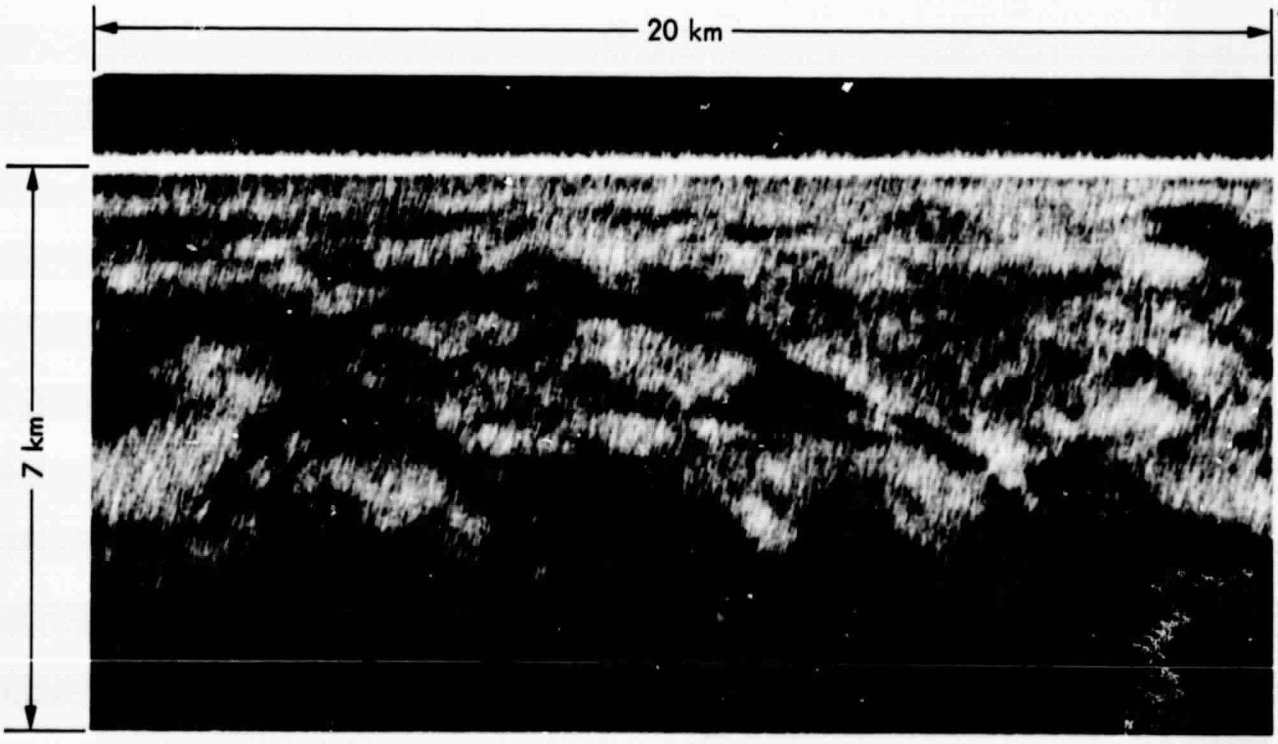

Fig. 16. Linear regions of smooth water

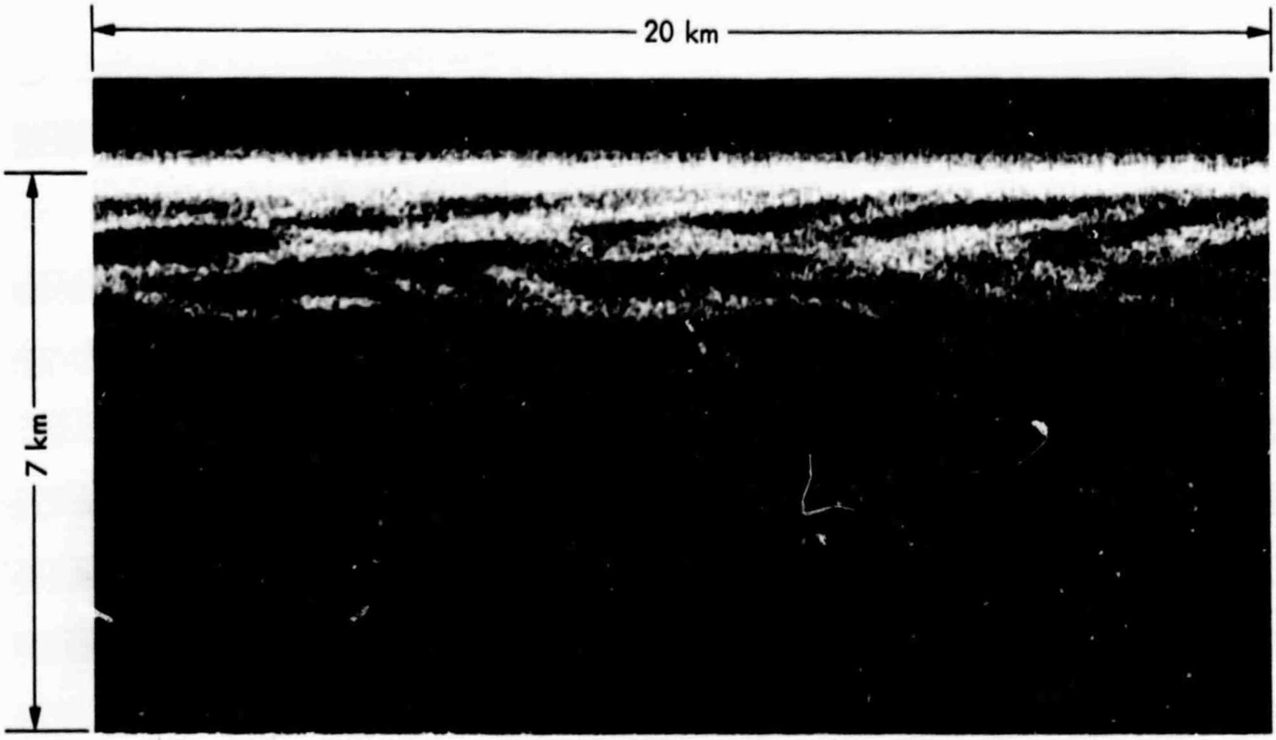

Fig. 17. Large linear periodic slicks

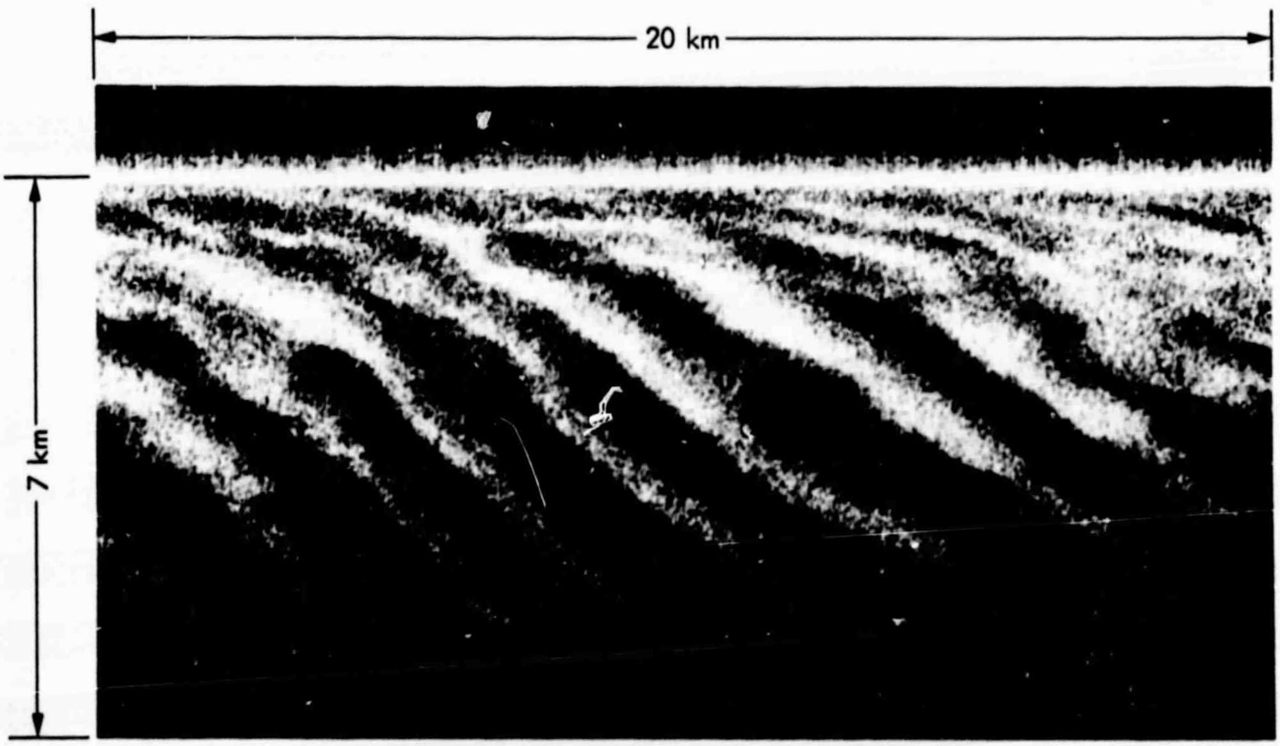

Fig. 18. Large linear periodic slicks; same as in Fig. 17, but observed from a different angle a few hours later

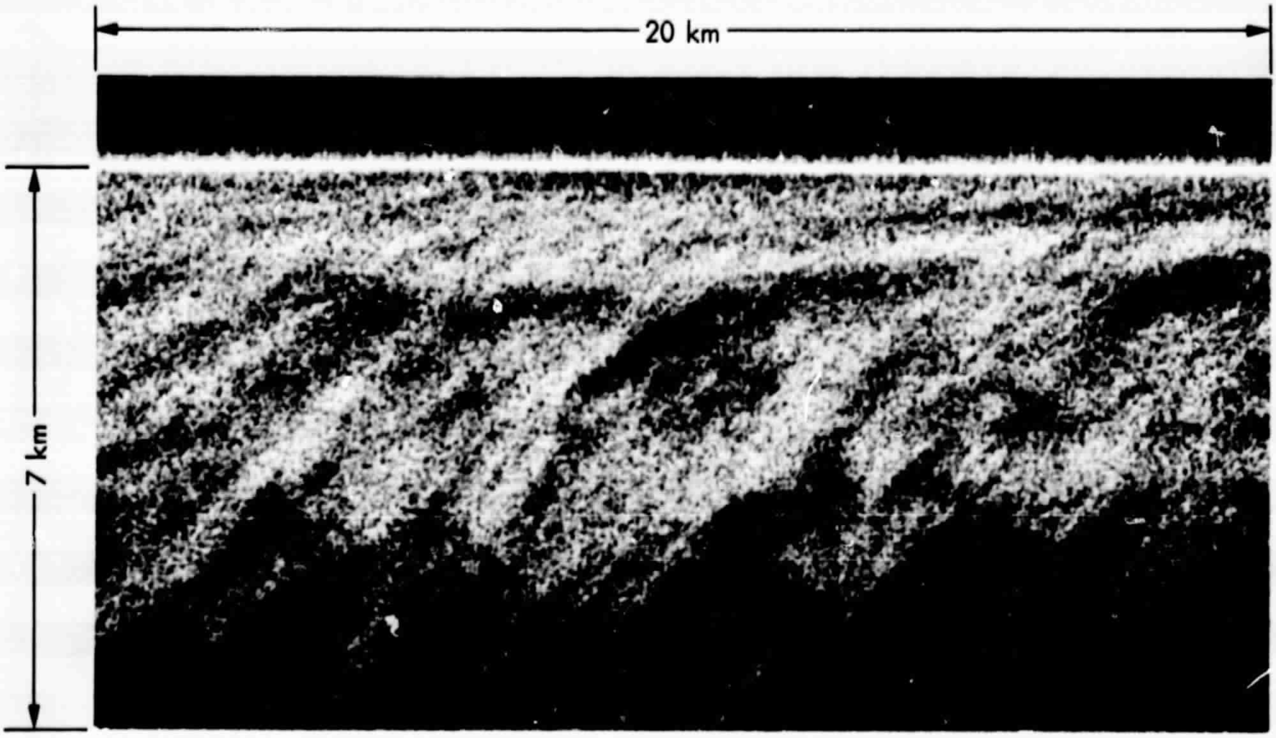

Fig. 19. Large patterns of roughness change

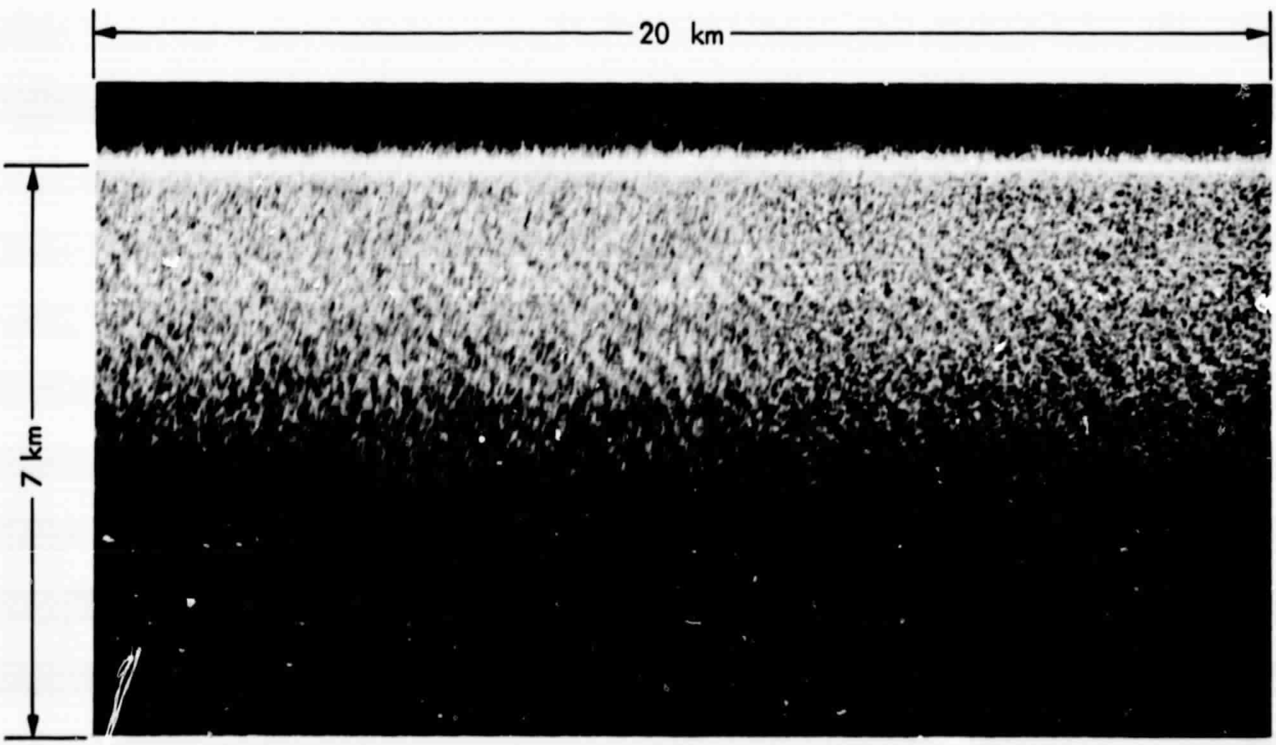

Fig. 20. Swells

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15. Supplementary Notes

16. Abstract

This report summarizes the type of data that was taken with the JPL imaging radar during the Global Atmospheric Research Program (GARP) Atlantic Tropical Experiment (GATE) mission and gives a representative sample of the data.

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