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REPORT ON THE FIRST MOS-1 DATA RECEIVED AT SYOWA STATION, ANTARCTICA

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Abstract: Data from Marine Observation Satellite 1 (MOS-1) were received starting from February 1989 at Syowa Station, Antarctica, by the newly installed Multi Purpose Satellite Data Receiving System (11 m antenna). The data of more than 200 paths are to be received per year, in order to study polar atmosphere, ice sheet and sea ice using three sensors, MESSR, VTIR and MSR. 2 HDDTs were brought back to Japan; they are composed of 13 paths acquired at the beginning of the system operation. Quick look films of these data were made, and some typical scenes of MESSR, VTIR and MSR were processed at NASDA EOC. Interesting features such as a giant iceberg are found among these processed images. Some limits of practical use of MESSR depending on the gain and solar elevation angle are discussed.

1. Introduction

Data acquisition of Marine Observation Satellite 1 (MOS-1) started from February 1989, following the installation of the Multi Purpose Satellite Data Receiving System at Syowa Station (69°00′S, 39°35′E), Antarctica by the Japanese Antarctic Research Expedition (JARE). The system is composed of an 11 m antenna with radome, receiver system, high density digital data recorder (HDDR) and minicomputer for data processing and quick look (EJIRI *et al.*, 1989). The facilities of the system were constructed by JARE-29 and -30. The system originally aimed to receive the data of the upper atmosphere-aurora-satellite EXOS-D (Institute of Space Research), and earth observation satellite, MOS-1, E-ERS-1 (European Remote-Sensing Satellite) and J-ERS-1 (Japanese Earth Resources Satellite). Though we had already been receiving the HRPT data of NOAA satellites by the L-band, 2.4 m antenna, this large receiving system of S and X bands has the strong advantage of acquiring high density data of the earth observing satellites as the first system in Antarctica.

The first series of MOS-1 data received at the station recorded on two HDDT (high density digital tape) were returned to the National Institute of Polar Research in April 1989, by the return voyage of "SHIRASE" with the summer party of JARE-30. In the present paper, examples of the first processed data are reported, and the JARE-30 MOS-1 observation plan at Antarctica is briefly introduced.

2. MOS-1

The Marine Observation Satellite 1 (MOS-1) was launched on February 1987 as the first Japanese earth observing, polar orbiting satellite (NASDA, 1985). Three sensors are on-board the satellite, the Multispectral Electronic Self Scanning Radiometer (MESSR), the Visible and Thermal Infrared Radiometer (VTIR) and the Microwave Scanning Radiometer (MSR), whose characteristics are shown in Table 1 (NASDA, 1985). The MESSR is a radiometer of high horizontal resolution, about 50 m field of view, similar to the MSS of Landsat. The VTIR is a medium resolution radiometer, similar to the NOAA AVHRR, however, the frequency of band 2 is special, located in the 6.3, μm water vapor band, and rather similar to the Meteosat. The MSR is roughly similar to the Nimbus-7 SMMR; however, the band frequencies are different and newly designed. The radiometric specifications of these radiometers are given in detail by Arai (1987). The satellite has the advantage of possessing multisensors of different frequencies and fields of view. Also, MOS-1 has a data collection system (DCS).

The MOS-1 is a polar orbiting, sun-synchronous satellite with inclination of approxmately 99 degrees, and mean altitude of about 909 km. It rotates around the earth 14 times a day and has a path recurrence frequency of 237 paths in 17 days. By receiving the satellite data at the similar time every day, we can obtain adjacent paths and cover the whole area. Figure 1 shows the positions of paths and rows of morning orbits around Syowa Station. Since the displacement of each pair of adjacent paths at 70°S is about 57 km, the MESSR scene can overlap by every other path and the MSR scene can overlap by every third path. The descending path crosses 70°S between 0800 and 0900 LT, and the equator between 1000 and 1100 LT.

Data of MESSR and VTIR are transmitted with X band (8 GHz) and those of MSR and telemetry with S band (2 GHz). Three sensors data of MOS-1 are recorded together on a 28-track high density digital tape (HDDT; 7 paths on 9200 ft tape) by

Table 1. Sensor specifications of MOS-1.

Item	MESSR	VTIR		MSR	
Wavelength	0.51–0.59 μm	0.5–0.7 μm		1.26 cm	
	0.61–0.69		6.0– 7.0 μm	(23.8±0.2 GHz)	
	0.72–0.80		10.5–11.5		0.955 cm
	0.80–1.1		11.5–12.5		(31.4±0.25 GHz)
Instantaneous field of view	54.7 μrad	1 m rad	3 m rad	1.89°	1.31°
(km)	0.05	0.9	2.7	32	23
Swath width (km)	100	1500		317	
Scanning method	push broom	mechanical		mechanical (conical scanning)	
Scan period	7.6 ms	1/7.5 s		3.2 s	
Detector	CCD	Si-PIN Diode	HgCdTe	Dicke type radiometer	
Radiometric resolution	39 dB at max	55 dB	0.5 K	<1 K	
Quantization level	64 (6 bits)	256 (8 bits)		1024 (10 bits)	
Data rate	8.78 Mbit/s	1.646 Mbit/s		2 kbit/s	

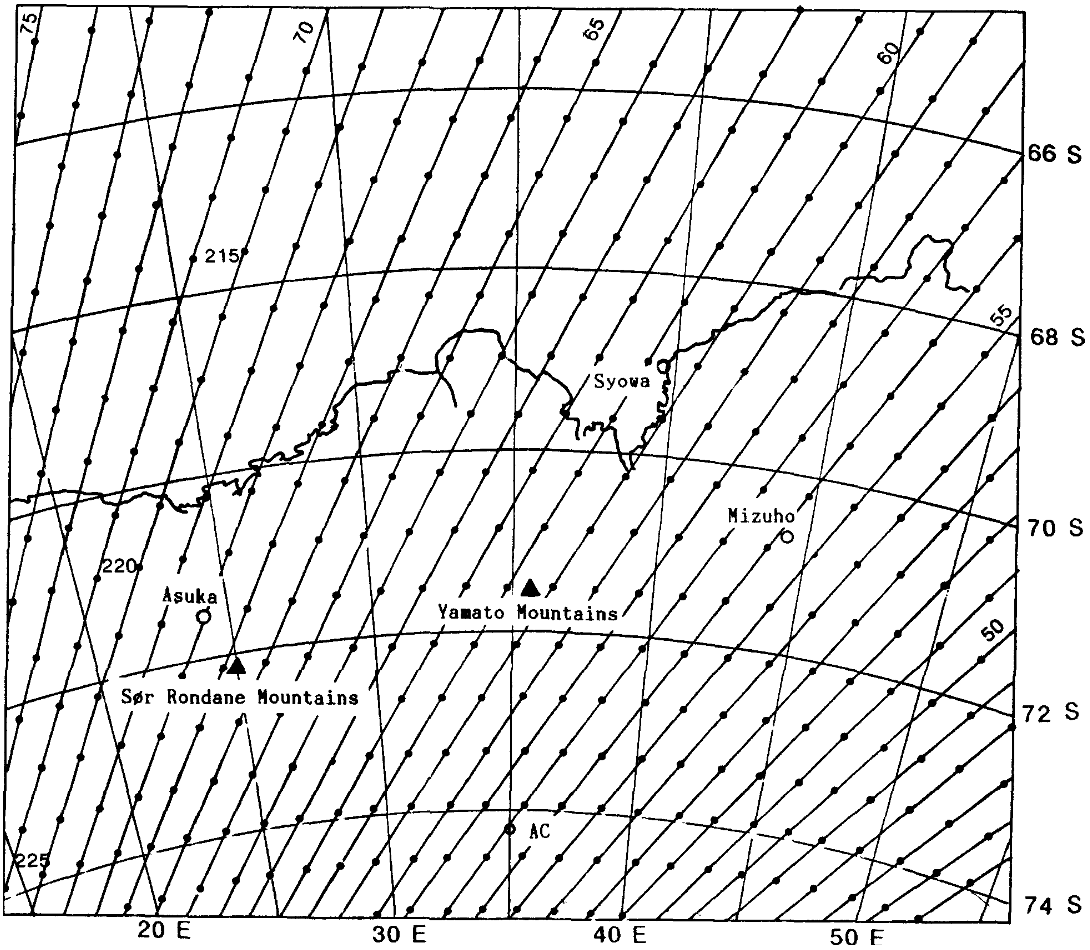

Fig. 1. Paths and rows (World Reference System) of MOS-1 descending orbits (morning) in the vicinity of Syowa Station.

the high density digital recorder (HDDR; Honeywell HD-96).

3. Operation Status

MOS-1 data are received at Syowa Station under an agreement (August 1986) between the National Space Development Agency (NASDA) and National Institute of Polar Research (NIPR). A request for observation is made by NIPR according to the research plan. Then the observation plan is decided and orbital parameters are sent by NASDA to NIPR and Syowa Station. At Syowa Station, data to HDDT are received and also quick look image photos (QL) are taken by the members of JARE. After the data (HDDT and QL) return to the NIPR, HDDTs are sent to NASDA Earth Observation Center (EOC), together with catalogues of HDDT and QL. The data are processed to levels 0, 1 and 2 by NASDA EOC upon request by NIPR. Levels 0, 1 and 2 of the processing are original uncorrected digital data, radiometric corrected data and radiometric and geometric corrected data (Map projections for the Antarctic data are "Polar Stereo" for MSR and VTIR, and "Universal Transverse Mercator" for MESSR), respectively. The processed data are sent back to NIPR by CCT and image films. These data are used for further analysis by scientists and cooperative scientists of NIPR. Also, the data can be distributed through RESTEC (Remote Sensing Technology Center of Japan) similar to normal data received at NASDA EOC.

4. Observation and Research Plan

The major research subjects using the MOS-1 data are set as follows:
(1) Analysis of seasonal and interannual variation of atmospheric water vapor and liquid water content mainly from the MSR data. Since it is difficult to derive water vapor and liquid water from the MSR data over snow and ice surfaces, analysis might be restricted to the open water area.
(2) Monitoring of the surface condition and the ice sheet edge, such as the shape of ice shelf and the edges of glaciers from MESSR data.
(3) Examine the method to derive sea ice information from the combined MESSR, VTIR and MSR data and analyze the surface condition of sea ice and the variation of sea ice extent.

MOS-1 data are being acquired according to the following principles by JARE-30 and 31.
(1) In order to cover the coastal region around Syowa Station by MESSR data, adjacent paths between paths 54 and 70 are received every other day during a few months in the summer half year (continuous receiving).
(2) In order to cover the research area by the MSR data and to obtain the time variations, one path is received every two or three days throughout the year (discrete receiving).
(3) Additional data are received for some research topics.
Data of about 200 to 250 paths are to be acquired every year and recorded on 30 to 40 HDDTs.

5. First Data Received at Syowa Station

Data of 13 paths received at Syowa Station at the beginning from February 12 to 24, 1989, were brought back with two HDDT. The 13 paths are listed in Table 2. The data of each path are composed of about a 15-minute record—about 60 scenes of MESSR image. Among 13 paths, 2 paths, paths 60 and 61, have a data loss just above Syowa Station, owing to the delay of antenna tracking. No troubles are found for other data.

Among these received data, some clear scenes of MESSR data around the coast and bare rock area (Yamato and Sør Rondane Mountains) were processed, together with some of the VTIR and MSR data at the NASDA EOC. Figure 2 is an example of MESSR imagery, showing the fast ice and pack ice area off Syowa Station. It also includes a giant 20×30 km iceberg in the middle of the scene. The small icebergs trapped in the fast ice are seen as spots at the bottom left thanks to the high surface resolution, about 50 m. The variation of surface albedo due to different snow and ice types is larger at longer wavelength; band 4 is the most sensitive among four bands

Table 2. Identification of 13 paths received at the beginning of operation of Multipurpose Satellite Receiving System at Syowa Station.

Date	Path	Row	Start time (UT)	Max el (°)	MESSR scene	HDDT No.
Feb. 12	66	189–248	0624: 15	69.1	E	89-2501
13	67	183–248	0629: 04	65.5	E	〃
13	220	233–297	2209: 15	57.2	W	〃
14	68	183–248	0635: 09	62.1	E	〃
14	221	233–297	2215: 16	54.9	W	〃
15	69	182–247	0641: 13	58.9	W	〃
15	222	233–296	2221: 17	52.7	E	〃
16	70	182–247	0647: 18	55.7	W	89-2502
17	54	187–252	0511: 08	67.8	W	〃
19	56	186–251	0523: 07	74.1	W	〃
20	57	186–251	0529: 08	77.5	W	〃
23	60	185–250	0547: 09	88.4	W	〃
24	61	184–250	0553: 10	87.9	W	〃

Table 3. Limitation of practical use of MESSR based on radiometric characteristics.

	Band 1	Band 2	Band 3	Band 4
Wave length (μm)	0.51–0.59	0.61–0.69	0.72–0.80	0.80–1.10
Radiance at the top of the atmosphere I_0 (mw·cm^{-2}·str^{-1})	4.898	4.148	3.157	7.843
Maximum radiance of the detector I_{max} (mw·cm^{-2}·str^{-1})	2.25	1.87	1.61	5.36
Solar elevation angle h that meets 80% albedo as I_{max} $h=\sin^{-1}(I_{max}/0.8/I_0)$	35.0°	34.3°	39.6°	58.7°
Same as above but with high gain (×3 for band 1 and 2, ×2 for 3 and 4)	11.0° (19 Mar. 23 Sep.)	20.8° (20 Mar. 21 Sep.)	18.6° (25 Feb. 11 Oct.)	25.3° (4 Feb. 30 Oct.)
Minimum radiance of the detector I_{min} (mw·cm^{-2}·str^{-1})	0.20	0.17	0.15	0.35
Solar elevation angle h that meets 30% albedo as I_{min} $h=\sin^{-1}(I_{min}/0.3/I_0)$	7.8° (28 Mar. 14 Sep.)	7.8° (28 Mar. 14 Sep.)	9.1° (24 Mar. 17 Sep.)	8.6° (26 Mar. 16 Sep.)
Same as above but with high gain	2.6° (13 Apr. 31 Aug.)	2.6° (13 Apr. 31 Aug.)	4.5° (7 Apr. 5 Sep.)	4.3° (7 Apr. 5 Sep.)

* Dates in ( ) correspond to the solar elevation angle h at the time of satellite pass at 70°S

of MESSR (WARREN, 1982; GRENFELL and PEROVICH, 1984; YAMANOUCHI *et al.*, 1986). We can find the difference in albedo of sea ice in the band 4 imagery, and no difference in the band 1 imagery, even though the output is not saturated.

Since observations by the MESSR need reflected solar radiation, its term of practical use is limited by the radiometric characteristics of the sensor (NASDA, 1985). Table 3 shows the estimated limits of the MESSR from the solar elevation at the time of satellite pass over Syowa Station. Since the radiometer has the maximum input limit, the output will be saturated if the input exceeds this limit. Even over the high

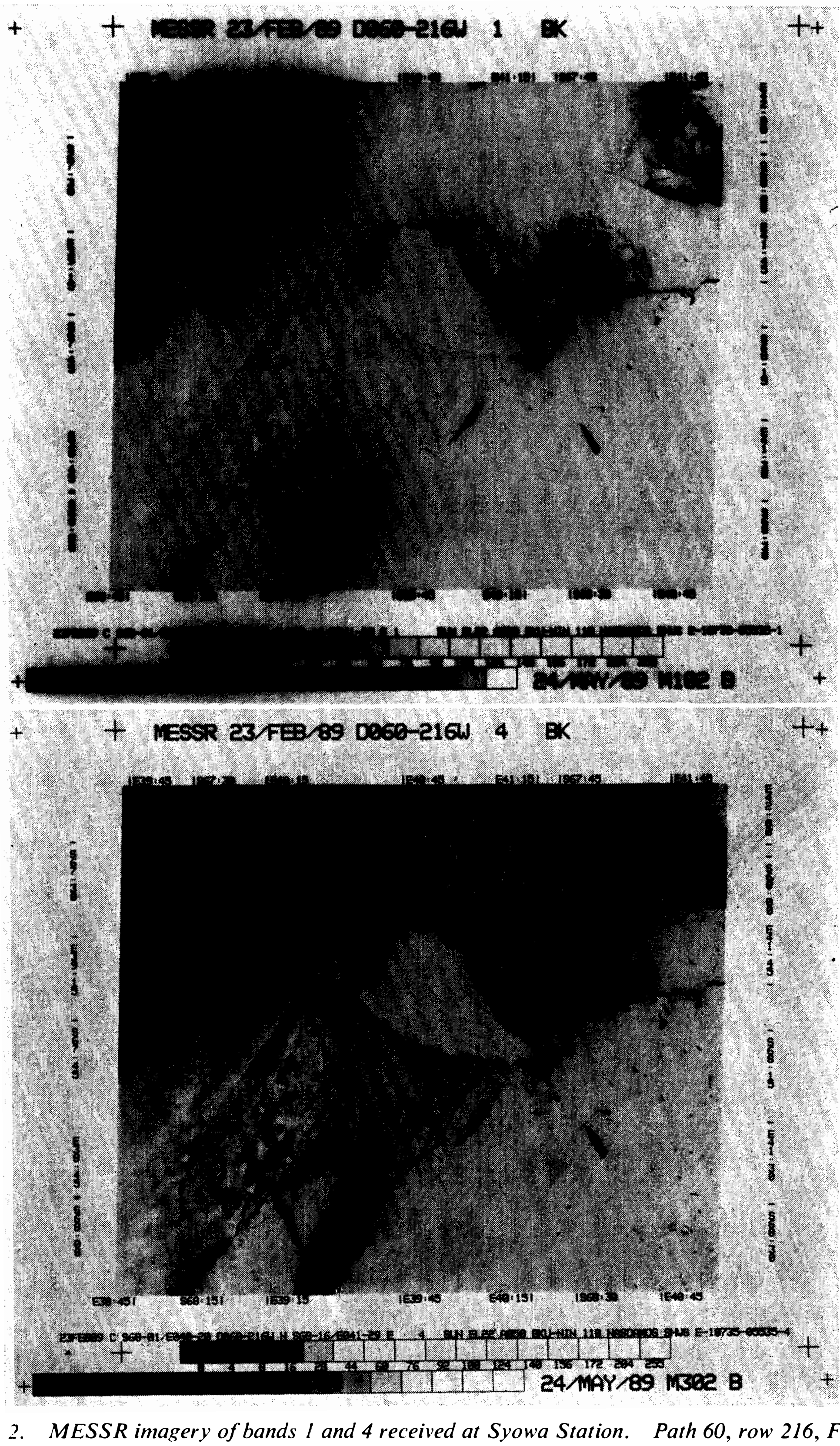

Fig. 2. MESSR imagery of bands 1 and 4 received at Syowa Station. Path 60, row 216, February 23, 1989.

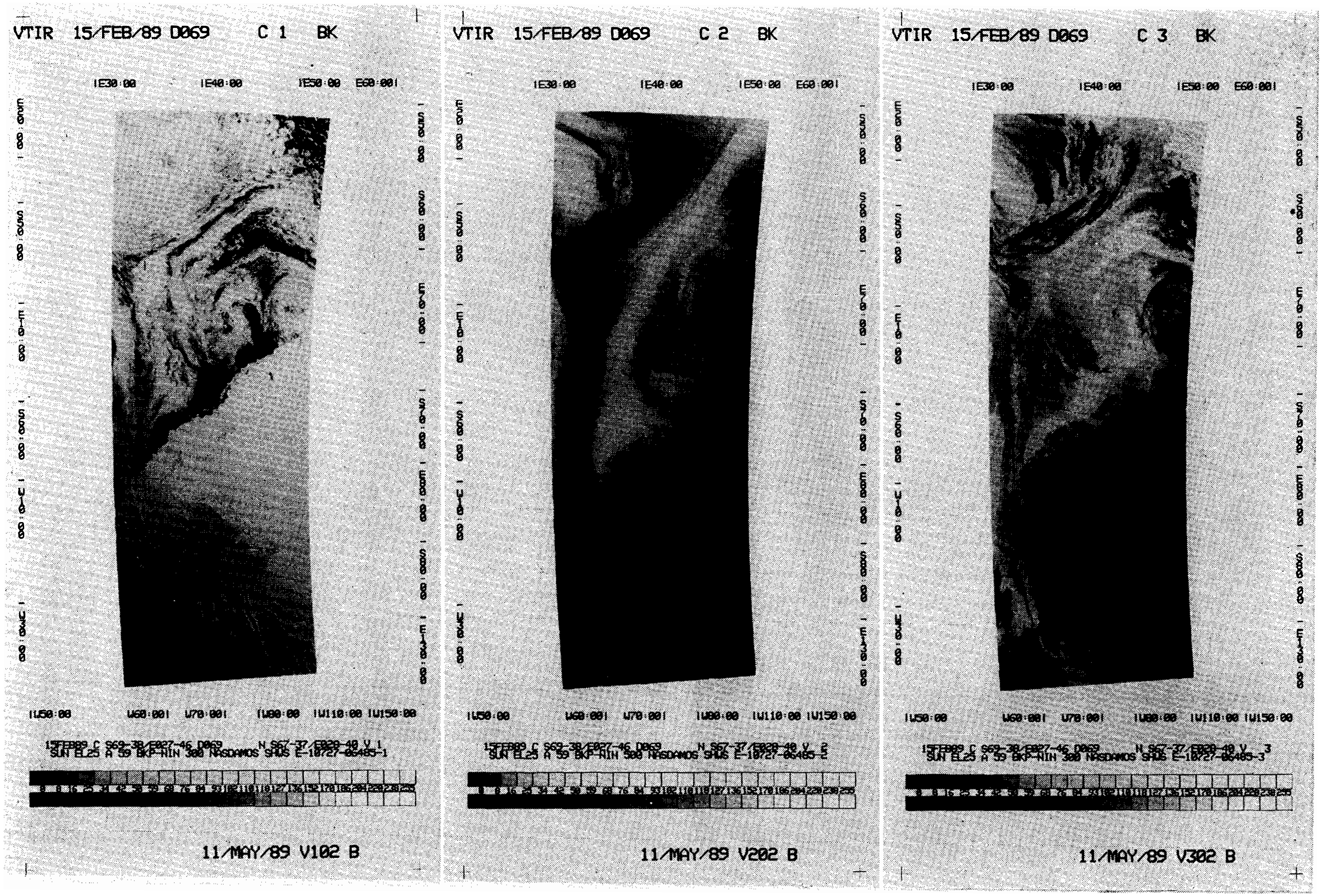

Fig. 3. VTIR imagery of channels 1, 2 and 3 of path 69 received at Syowa Station on February 15, 1989.

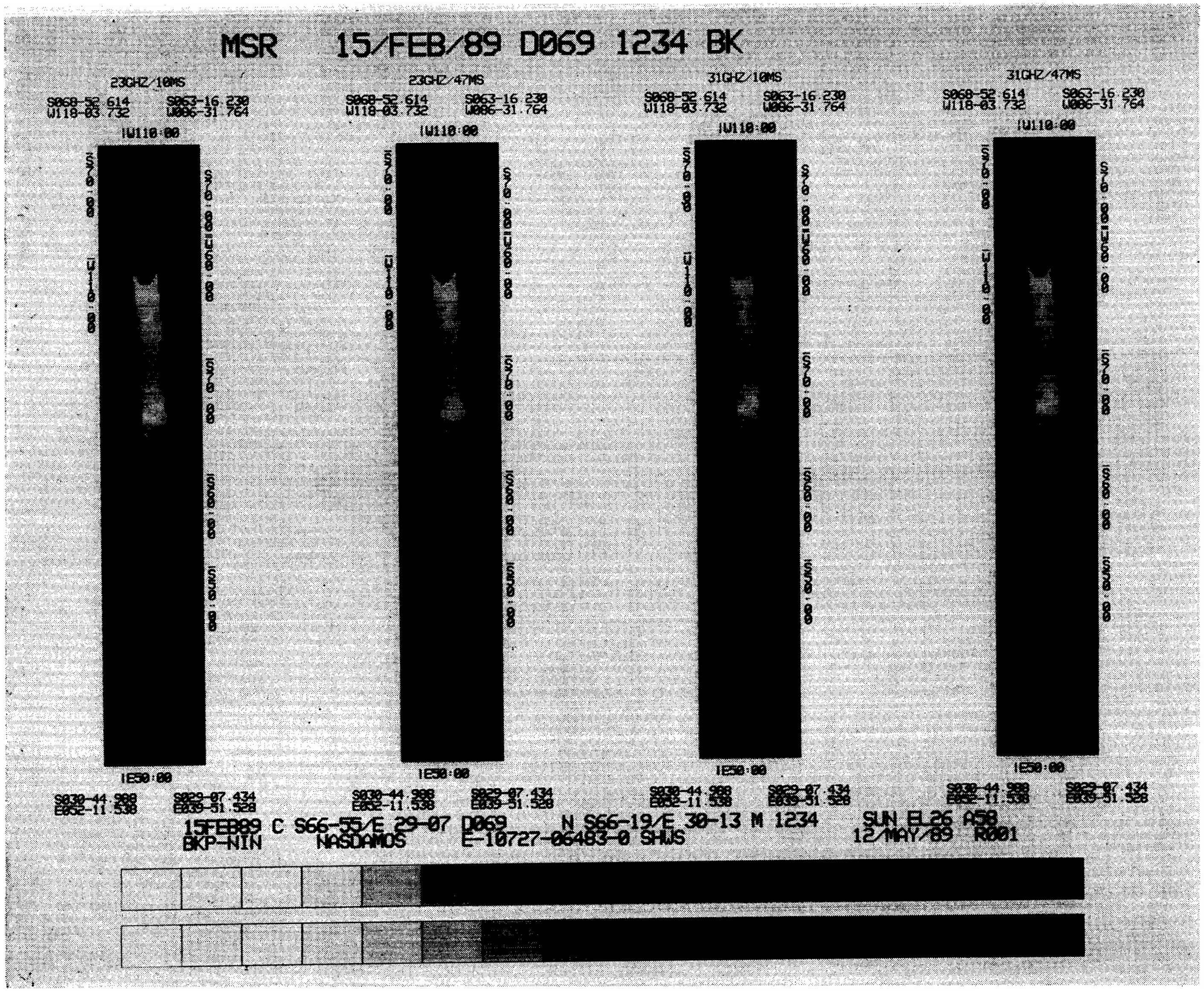

Fig. 4. MSR imagery of channels 1 (23 GHz, 10 ms), 2 (23 GHz, 47 ms), 3 (31 GHz, 10 ms) and 4 (31 GHz, 47 ms) of path 69 received at Syowa Station on February 15, 1989.

albedo snow surfaces (albedo at the top of the atmosphere is assumed as about 0.8 after YAMANOUCHI *et al.*, 1986), a radiometer with normal gain will not be saturated throughout the year at the time of receiving, because the maximum solar elevation angle at 0830 LT near the solstice is about 33° at Syowa Station. The high gain, which is three times as efficient for bands 1 and 2 and twice as efficient for bands 3 and 4 as for normal gain, is usable after March 20 or before September 21. On the other hand, from the minimum input radiance, in order to discriminate 30% planetary albedo (middle value between the open water and sea ice of some thickness) the MESSR data are only practically usable when the solar elevation is higher than 7.8° (until March 28 and from September 14) at normal gain, and when the solar elevation is higher than 2.6° (till April 13 and from August 31) at high gain.

Figure 3 shows an example of VTIR imagery. These images are about 1500 km wide and 5000 km long, with a pixel size of 0.9 km (at 60°S). Since the standard processing to level 2 at the EOC was restricted to −40°C, no features are seen inland on the continent in channels 2, 3 and 4 images (at present, extended to −80°C). Flow patterns of water vapor in the upper layer are seen in the channel 2 image, different from the cloud pattern in the channel 3 image.

Figure 4 shows an example of MSR imagery from the same path as Fig. 3. These images are of about 300 km wide and 5000 km long, with a pixel size of 10 km (at 60°S). The white area is the Antarctic continent; the black area is the ocean. Rough features in the black ocean may correspond to a dense cloud pattern.

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References

ARAI, K. (1987): Pleliminary assessment of radiometric accuracies for MOS-1 sensors. Int. J. Remote Sensing, **9**, 5–21.

EJIRI, M., TAMAGAWA, S., ENDO, K., KUZUYA, R. and CHIBA, M. (1989): Multi purpose satellite data receiving antenna. Proc. ISAP '89, 655–658.

GRENFELL, T. C. and PEROVICH, D. K. (1984): Spectral albedos of sea ice and incident solar irradiance in the Southern Beaufort Sea. J. Geophys. Res., **89**, 3573–3580.

NATIONAL SPACE DEVELOPMENT AGENCY of JAPAN (1985): MOS-1 to ground station interface description. Rev. 1, HE-85317.

WARREN, S. G. (1982): Optical properties of snow. Rev. Geophys. Space Phys., **20**, 67–89.

YAMANOUCHI, T., SUZUKI, K., MATSUSHITA, M., SHIMIZU, M. and NAITO, Y. (1986): Determination of sea ice concentration from AVHRR visible and near infrared imagery. Nankyoku Shiryô (Antarct. Rec.), **30**, 89–102.

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