—研究ノート—
Scientific Note

Preliminary Study of Ice Flow Observations along Traverse Routes from Coast to Dome Fuji, East Antarctica by Differential GPS Method

Hideaki MOTOYAMA[1], Hiroyuki ENOMOTO[2], Teruo FURUKAWA[1], Kokichi KAMIYAMA[1], Hitoshi SHOJI[2], Takayuki SHIRAIWA[3], Kazuo WATANABE[4], Kunihisa NAMASU[4] and Hisataka IKEDA[4]

GPS相対測位による東南極の沿岸からドームふじ間の氷河流動の観測（序報）

本山秀明[1]・榎本浩之[2]・古川晶雄[1]・神山孝吉[1]・庄子　仁[2]・
白岩孝行[3]・渡辺和夫[4]・生巣国久[4]・池田尚應[4]

要旨：GPS相対測位による東南極のS16からドームふじに至るトラバースルートに沿っての氷河流動観測が1992年から行われている．このGPS衛星を利用しての相対測位法は，従来の衛星を用いたJMR法や三角鎖法より野外では簡便な観測法である．観測誤差は，2地点間の距離の100万分の1以内に収まる．同一地点の1年平均の氷河の流動速度と方向は安定していた．

Abstract: Ice flow has been observed along traverse routes from S16 to Dome Fuji, East Antarctica using the differential GPS (Global Positioning System) method since 1992. This positioning method is easier to use in the field than the satellite doppler positioning system (JMR) or triangle chain method. The vertical and horizontal error of positioning was within 1 ppm of base line. The horizontal speed and direction of ice flow were almost the same both years at each site.

1. Introduction

A five-year glaciological program, the deep ice coring project at Dome Fuji, was started in 1992. In 1991 and 1992, the 32nd and 33rd Japanese Antarctic Research Expeditions (JARE-32 and JARE-33) extended the new route from Mizuho Station to Dome Fuji, about 1000 km from Syowa Station (FUJII, 1992; KAMIYAMA *et al.*, 1994). These traverse routes are shown in Fig. 1.

The main glaciological field work was carried out along oversnow traverse routes from Syowa Station to Dome Fuji. NARUSE (1978) and NISHIO *et al.* (1989) analyzed the ice flow on Mizuho Plateau by the chain survey method and by satellite

[1] 国立極地研究所. National Institute of Polar Research, 9-10, Kaga, 1-chome, Itabashi-ku, Tokyo 173.
[2] 北見工業大学. Kitami Institute of Technology, 165, Koen-cho, Kitami 090.
[3] 北海道大学低温科学研究所. Institute of Low Temperature Science, Hokkaido University, Kita-19, Nishi-8, Kita-ku, Sapporo 060.
[4] 国土地理院. Geographical Survey Institute, 1, Kitasato, Tsukuba 305.

南極資料, Vol. 39, No. 2, 94-98, 1995
Nankyoku Shiryô (Antarctic Record), Vol. 39, No. 2, 94-98, 1995

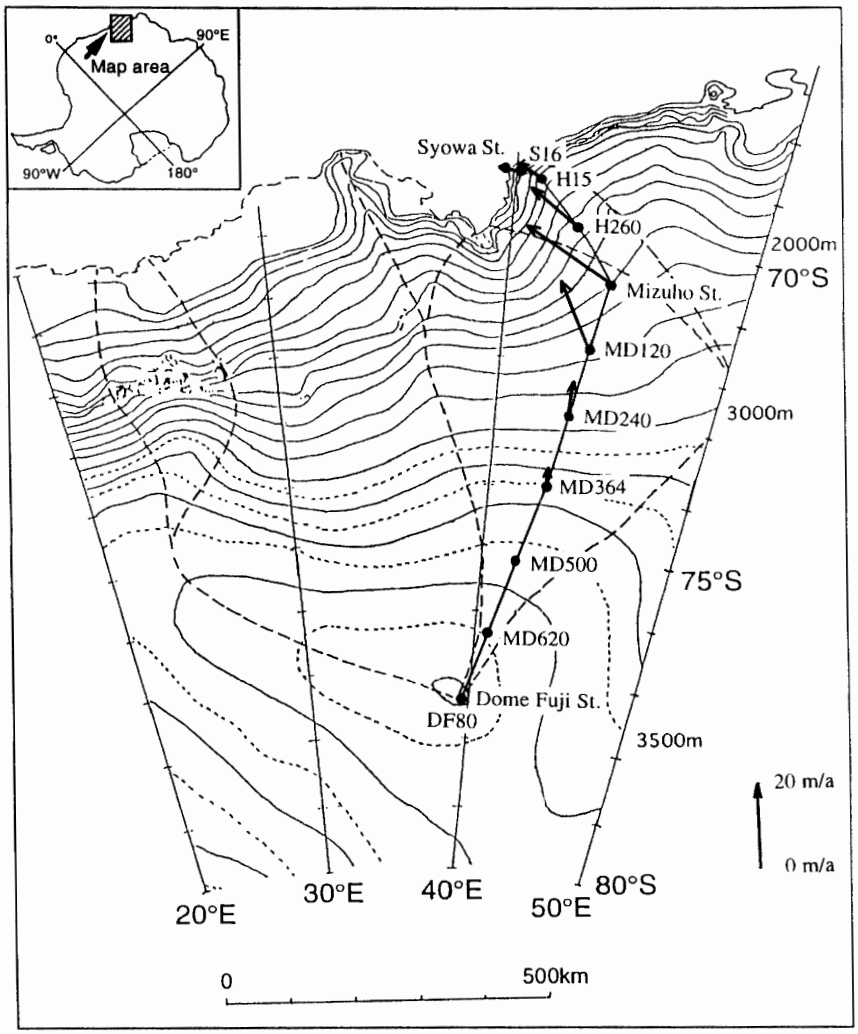

Fig. 1. Location map of GPS observations. Arrows indicate horizontal vectors of ice flow (m/a). Broken line shows the boundary of drainage basin.

doppler positioning system (JMR-4A), respectively. Recently, the position and altitude can be determined easily by Global Positioning System (GPS). The differential GPS method (NIPPON SOKUCHI GAKKAI (Geodetic Society of Japan), 1989; TOU and SHIBUYA, 1993) was applied to observe the glacier ice flow on traverse routes.

2. Observations

The synchronous GPS observations were conducted at Syowa Station and GPS stations along traverse routes (KAMIYAMA *et al.*, 1994; MOTOYAMA *et al.*, 1995). Using synchronous data, the distance and height difference were calculated precisely by the differential GPS method. These errors were within 1 ppm of distance between two stations. The GPS station as datum point was set up on an exposed rock at Syowa Station. The 11 GPS stations along traverse routes on the ice sheet were set

Table 1. Position of GPS station and observational period.

	(WGS-84)			Observational period			
	Latitude*	Longitude*	Altitude*	Jan. 1992	Jan. 1993	Dec. 1993	Jan. 1994
Syowa Station	69° 00′S	39° 35′E	42(m)	o	o	o	o
S16	69° 02′S	40° 03′E	589	o	o		o
H15	69° 05′S	40° 47′E	1049	o	o		o
H260	69° 53′S	42° 41′E	1774	o	o		o
Mizuho Station	70° 42′S	44° 17′E	2248	o	o		o
MD120	71° 50′S	43° 53′E	2599	o	o		o
MD240	72° 54′S	43° 28′E	2999	o	o		o
MD364	74° 00′S	43° 00′E	3351	o	o		o
MD500	75° 14′S	42° 01′E	3570				o
MD620	76° 18′S	40° 50′E	3718				o
Dome Fuji Station	77° 19′S	39° 42′E	3800			o	o
DF80	77° 22′S	39° 37′E	3799				o

* Calculated result of 1994 by differential GPS method based on Syowa Station.

up by JARE-33 and JARE-34. GPS stations with their positions and elevations are listed in Table 1. The stations S16, H15 and H260 are in the Sôya drainage basin. Other stations are in the Shirase drainage basin. Dome Fuji is at the top of this basin.

The type of GPS receiver was 4000 SST (Trimble Navigation Co., Ltd). The observed period was 6–8 hours with collection rate 15 s, elevation limit 15 degrees, minimum number of satellite 4.

3. Results

3.1. Long term observations at Dome Fuji Station

The long term synchronous GPS observations were carried out at Syowa Station and at Dome Fuji Station from December 23, 1993 to January 4, 1994. An observational period was from 1 hour to 20 hour (depend on electrical power condition) each day. The base line vectors were calculated using the differential GPS method. The horizontal distance and vertical difference of two stations are shown in Fig. 2a and b, respectively. Standard deviations of the base line vector were around 0.01 m. Distance between two stations is about 1000 km. So that the precision of the differential GPS method was 1 m (1 ppm of 1000 km). These figures indicate that the error was to be expected within 1 m or 1 ppm, on the assumption that the position of Dome Fuji Station did not move during the observation period.

3.2. Characteristics of flow rate

The positions of GPS stations along traverse routes from S16 to MD364 were observed three times, in January 1992, 1993, and 1994 (Table 1). The rates of ice flow for two periods are summarized in Table 2. The correction of snow densification was

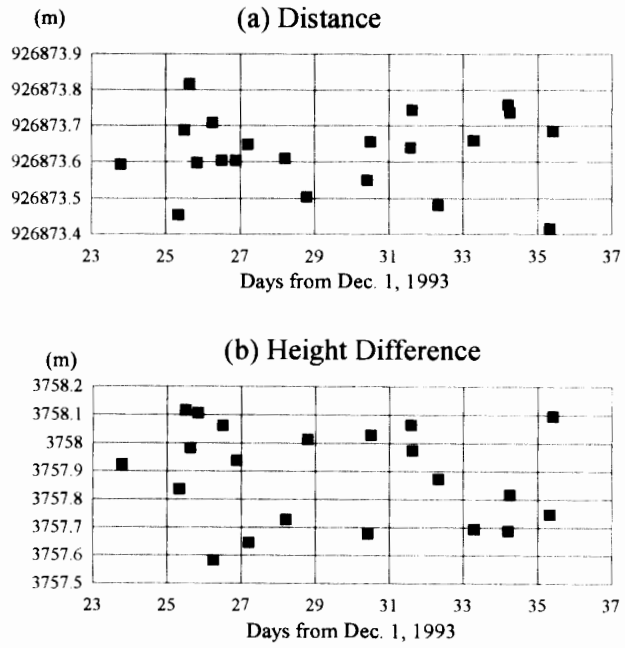

Fig. 2. Variation of measured position at Dome Fuji Station.
(a) Distance from Syowa Station. (b) Height difference from Syowa Station.

Table 2. Flow rates along traverse route (m/annual).

		Flow rate	Latitudinal component (south +)	Longitudinal component (east +)	Vertical component (up +)
S16	1992-1993	5.2	−1.6	−4.9	(−0.6)
	1993-1994	5.0	−1.9	−4.5	(0.4)
H15	1992-1993	6.7	−3.3	−5.8	(−1.5)
	1993-1994	7.1	−3.5	−6.1	(−0.2)
H260	1992-1993	14.5	−8.6	−11.7	(−0.9)
	1993-1994	14.6	−8.7	−11.7	(0.4)
Mizuho Station	1992-1993	22.2	−10.2	−19.6	(−0.4)
	1993-1994	22.1	−10.1	−19.6	(0.4)
MD120	1992-1993	17.8	−15.7	−8.3	(0.0)
	1993-1994	17.7	−15.7	−8.2	(0.0)
MD240	1992-1993	8.0	−8.0	−0.9	(−0.3)
	1993-1994	8.1	−7.9	−1.0	(0.2)
MD364	1992-1993	4.1	−4.1	−0.1	(−0.1)
	1993-1994	4.0	−3.9	−0.2	(−0.3)

not considered in these analyses. There are no significant differences of horizontal ice flow rates between two years at any station. Otherwise, the vertical flow rates cannot be discussed in detail, because of lack of data.

The horizontal vectors of ice flow are shown in Fig. 1. Direction and speed in the Shirase drainage basin are seen to have almost the same tendency as in previous observations (NISHIO *et al.*, 1989; NARUSE, 1978). The ice flow in Sôya drainage basin shows that the speed of ice flow was faster at H260 upstream than S16 downstream.

4. Conclusion

Ice flow was observed along traverse routes from S16 to Dome Fuji, East Antarctica using the differential GPS method. This positioning method is easly to use in the field. The error of position was within 1 ppm of base line.

The horizontal speed and direction of ice flow were almost same during by the observational periods, but the vertical movement is curious. The observation of ice flow is continuing five-year glaciological program, the deep ice coring project at Dome Fuji.

Acknowledgments

We would like to express sincere thanks to all members of JARE-33, JARE-34, JARE-35, led by Profs. M. FUKUCHI, N. SATO, and O. WATANABE of the National Institute of Polar Research respectively, who extended generous support in the field work.

References

FUJII, Y. (1992): Dai-32-ji Nankyoku Chiiki Kansoku-tai Syowa Kiti ettô (1991) hôkoku (Activities of the wintering party at Syowa Station by the 32nd Japanese Antarctic Research Expedition in 1991). Nankyoku Shiryo (Antarct. Rec.), **36**, 441–472.

KAMIYAMA, K., FURUKAWA, T., MAENO, H., KISHI, T. and KANAO, M. (1994): Glaciological data collected by the 33rd Japanese Antarctic Research Expedition in 1992. JARE Data Rep., **194** (Glaciology 21), 67p.

MOTOYAMA, M., ENOMOTO, H., MIYAHARA, M. and KOIKE, J. (1995): Glaciological data collected by the 34th Japanese Antarctic Research Expedition in 1993. JARE Data Rep., **202** (Glaciology 23), 42p.

NARUSE, R. (1978): Surface flow and strain of the ice sheet measured by a triangulation chain in Mizuho Plateau. Mem. Natl Inst. Polar Res., Spec. Issue, **7**, 198–226.

NIPPON SOKUCHI GAKKAI (1989): GPS-Jinko eisei ni yoru seimitsu sokui shisutemu-(GPS-Precise survey system using satellite observation-). Tokyo, Nippon Sokuryo Kyokai, 272p.

NISHIO, F., MAE, S., OHMAE, H., TAKAHASHI, S., NAKAWO, M. and KAWADA, K. (1989): Dynamical behavior of the ice sheet in Mizuho Plateau, East Antarctica. Proc. NIPR Symp. Polar Meteorol. Glaciol., **2**, 97–104.

TOU, H. and SHIBUYA, K. (1993): Difarensharu GPS sokui kara motometa Mizuho Kôgen seibu no hyôshô hendo (Glacier flow of west Mizuho Plateau by differential GPS observation). Gekkan Chikyu, **5**, 440–444.

(Received January 8, 1995; Revised manuscript received March 14, 1995)