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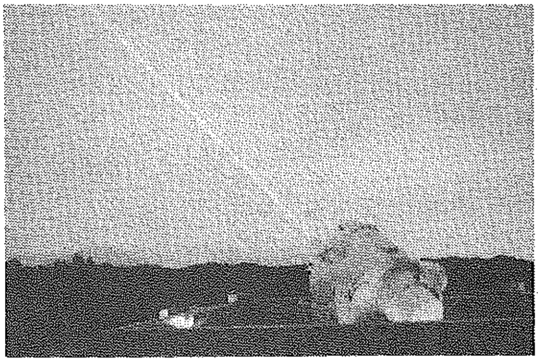

海 上 保 安 庁

DATA REPORT
OF
HYDROGRAPHIC OBSERVATIONS

SERIES OF SATELLITE GEODESY

No. 1, March 1988

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MARITIME SAFETY AGENCY
TOKYO, JAPAN

Compiled by the Hydrographic Department of Japan (JHD).
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104 Japan.

DATA REPORT
OF
HYDROGRAPHIC OBSERVATIONS

SERIES OF SATELLITE GEODESY

No. 1, March 1988

SATELLITE LASER RANGING AT HYDROGRAPHIC DEPARTMENT, LAUNCH OF JAPANESE GEODETIC SATELLITE AJISAI AND ESTABLISHMENT OF SATELLITE GEODESY OFFICE

Summary – The Hydrographic Department of Japan (JHD) has carried out satellite geodesy including satellite laser ranging observation. On August 13, 1986, the Japanese geodetic satellite Ajisai was launched. The observation of the satellite will play the most important part in the project of establishing the marine geodetic control network by JHD. Also, to cope with the services mainly concerning the new satellite, the Satellite Geodesy Office was established in JHD in April, 1986.

Key words: satellite laser ranging – marine geodetic control network – Ajisai – Satellite Geodesy Office

1. Introduction

Since the first launch of artificial satellite in the world in 1957, the Hydrographic Department of Japan (JHD) has been interested in the geodesy using artificial satellites.

In the 1960's, the JHD carried out satellite geodesy making use of the satellites Echo I, II and the geodetic satellite Pageos and determined the positions of several off-lying islands around Japan. However, as the observation was made only by photographing of the satellites, the accuracy was estimated to be a few tens of meters.

In the 1970's the determination of off-lying islands by the use of navigation satellite system, namely, the Navy Navigation Satellite System (NNSS) was introduced. The positions of many islands were determined by the so-called Doppler observations of NNSS satellites. At this period, however, the receiver employed for the observation was that on board the survey vessels.

The relative positions between the antenna on the ship and the fixed points on the islands could not be measured so rigorously. Also it was performed by the point positioning method. Thus the accuracy of positioning using the NNSS in this period is not so good. It is also estimated to be a few tens of meters.

Although the accuracies in both photographic observation of satellites and the NNSS observation were quite insufficient from the present point of view, the results contributed greatly to correct the positions of many off-lying islands which had been determined astronomically in the old days and had the difference from the geodetic positions referred to the Tokyo Datum amounting to more than 1000 meters in some cases.

Also the results have been reflected on the preparation of the nautical charts published by the JHD, i.e. in the newly published or revised charts the positions of the off-lying islands are corrected based on the results of the satellite observations for those islands where the observations were carried out.

Recently, in the context of the demarcation of the jurisdictional sea, a high accuracy for the coordinates of many off-lying islands has come to be required, and a quite new full-scale geodetic work has been commenced by the JHD by the methods of Satellite Laser Ranging (SLR), translocation observations of navigation satellites and so on. Also the Japanese geodetic satellite was launched for supporting our work. And to cope with these situations a new office namely the Satellite Geodesy Office was established in the JHD.

This article summarizes the SLR observation at the JHD and the services of the newly established Satellite Geodesy Office.

2. Marine geodetic control network

For the purpose of the exact demarcation of the boundaries of the so-called jurisdictional sea such as the territorial sea or the exclusive economic zone which were provided in the Convention on the Law of the Sea, the project of establishing the marine geodetic control network was commenced by the JHD in 1980. This project is necessary to be performed by a full scale satellite geodesy with high accuracy. The project consists of the following three stages:

a) The connection of the Tokyo Datum to a worldwide geodetic system.

This is carried out by observing the U.S. geodetic satellite Lageos at the Simosato Hydrographic Observatory (SHO) where the fiducial point of the marine geodetic control network is established. An SLR system was installed for this purpose at the SHO and the observation has been made since April, 1982.

b) The connection of the principal off-lying islands to the Tokyo Datum.

Comparatively large off-lying islands which are not connected to the main land geodetically at all or connected very poorly are incorporated into the Tokyo Datum by the observation of the Japanese geodetic satellite "Ajisai" on which the explanation is given in the below.

The SLR observation and direction observation by photographing of Ajisai are made simultaneously at the SHO and on the island. This observation will start in January, 1988. The point whose position is determined by the observation of Ajisai is called the first order control point.

c) The connection of the second order control points to the first order ones.

On smaller islands are set up the second order control points. The positions of these points are connected to the nearby first order control points by the NNSS observation. In this case the translocation method is applied in order to attain a high accuracy. This observation has been continued since 1980. In the near future the observation of the Global Positioning System (GPS) will take the place of that of the NNSS.

Besides, many third order control points are set up near each second order point. Their positions are determined by the usual survey using a theodolite and a distance meter, not by the satellite technique.

In Figure 1, the location of the control points of each order is shown.

3. SLR observation at JHD

Since 1982, the SLR observation of the US geodetic satellites Lageos and Beacon-C and the French geodetic satellite Starlette has been continued at the SHO for the purpose of determining the relation between the Tokyo Datum and a worldwide geodetic system. The observation data have been reported annually in the Data Report of Hydrographic Observations, Series of Astronomy and Geodesy, so far, and from this year in the Series of Satellite Geodesy of the same Report. Since August, 1986, the ranging to Ajisai has been made in place of Beacon-C.

Instruments

The first SLR system which is of fixed type was installed at the SHO in March, 1982, and it has been in operation since then. The system will be overhauled as well as a function of measuring the times of the flash-lights from Ajisai will be attached during the fiscal year of 1987.

A new transportable SLR system which is to be transported to islands in order to make SLR observation there will be completed in October, 1987. The specifications and capacity of the both systems are listed in Table 1 to meet the convenience of comparison.

Besides, a satellite camera for direction observation of Ajisai at SHO will be completed also in October, 1987. It is equipped with the objective lens of 20 cm in diameter, the automatic plate exchanger, the very precise driving mechanism, etc..

As for the satellite camera which is to be operated on the islands, an astro-camera which was used in the satellite observation in 1960's is alloted to the purpose with some remodeling.

International cooperation

The work of determining the position of the fiducial point at the SHO in the frame of a worldwide geodetic system requires the observation of geodetic satellites in cooperation with many other SLR stations distributed all over the world and the exchange of the data obtained at each station. While, the National Aeronautics and Space Administration (NASA) of the U.S. is promoting an international project called the Crustal Dynamics Project (CDP) in which many SLR as well as VLBI stations are participating and all the obtained data are

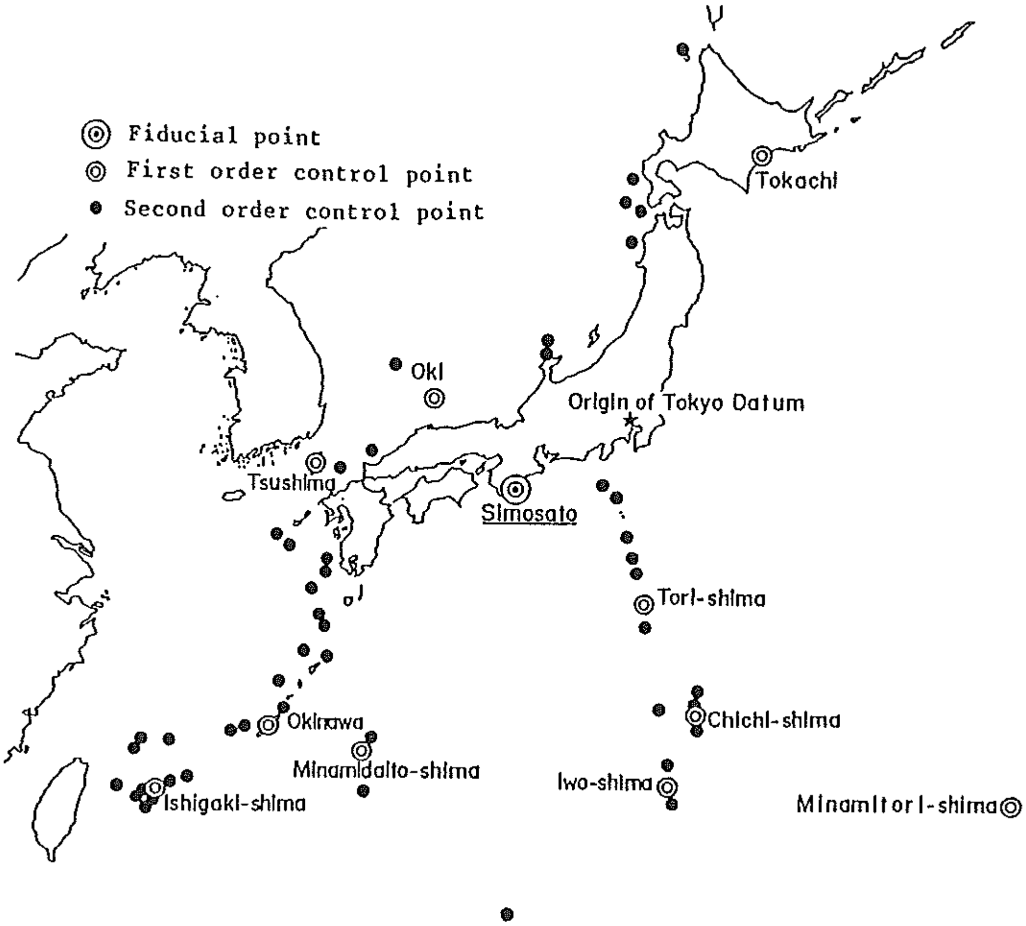

Figure 1. Marine geodetic control network

Table 1. Comparison of capacities between the fixed-type and transportable SLR systems of JHD

Item	Fixed-type	Transportable
Apperture of receiving telescope	60 cm	35 cm
Length of laser light	532 nm	532 nm
Output energy of emitted laser pulse	150 mJ	50 mJ
Width of laser pulse	200 ps	100 ps
Repetition rate of laser shot	4 /sec	5 /sec
Ranging precision per shot	9 cm	5 cm*

* expected

Table 2. Nominal and actual orbital elements of Ajisai

Nominal Elements		
Epoch	46654.9058 ('86 Aug. 12 $21^h44^m21.^s6$ UTC)	
a	7869.7 km	(daily variation)
e	0.001141	–0.0000164 /day
i	49.968 deg	–0.00005 deg/day
ω	183.304 deg	+2.45186 deg/day
Ω	253.085 deg	–3.07147 deg/day
M_o	285.508 deg	
n	12.434750 rev/day	–0.0931E-6 rev/day^2
Actual Elements		
Epoch	46674.0 ('86 Sept. 1 0^h UTC)	
a	7866.3 km	(daily variation)
e	0.000391	–0.0000109 /day
i	50.007 deg	–0.00036 deg/day
ω	281.736 deg	+2.58103 deg/day
Ω	194.269 deg	–3.07411 deg/day
M_o	307.363 deg	
n	12.443568 rev/day	–0.6159E-6 rev/day^2

Table 3. Designed and confirmed functions of Ajisai

Function	Designed	Confirmed
Spin rate	40 ± 4 rpm	40.3 rpm
Orientation of rotational axis	perpendicular to Earth equator, no free nutation	satisfactory
Brightness	2 ∼ 4 mag	∼ 2 mag
Reflection of laser	receivable at SLR stations	received at many SLR stations

collected at the Data Center of the project. So it was expected that if the JHD participated in this project, the necessary data would be provided from the Data Center in return for offering the data obtained at the SHO.

For the purpose of exchange of the SLR data as well as information on the hardware of SLR system and the software such as computer programs for orbit analysis or prediction, an agreement was reached between the JHD and the NASA in December, 1982.

The discussion between the JHD and the NASA for the preparation of the agreement had been continued since the spring of 1982 seizing such opportunities as the visit of important persons of the NASA to Japan for some conferences. And finally in December, 1982, the letters of agreement were exchanged between the director general of JHD and the director of international affairs of NASA. This was done under the control of the Standing Senior Liaison Group (SSLG) for the Japan-U.S. cooperation in non-energy fields.

When the Japanese geodetic satellite Ajisai was launched in August, 1986, the agreement was extended to include the cooperative observation as well as the exchange of the data and information concerning Ajisai. The agreement was realized in the form of the exchange of new letters in August 1, 1986, between the persons in the same positions as in the parent agreement. The letters of agreement for general cooperation and for Ajisai are listed as the Annex A and B.

This JHD-NASA cooperation is one of the bilateral cooperation between the governments. The JHD has other bilateral cooperational relations on the intergovernmental level with Centre D'Etudes et de Recherches Geodynamiques et Astronomiques (CERGA) in France, Institute of Applied Geodesy (IFAG) in West Germany, Shanghai Observatory and Institute of Seismology in China and Division of National Mapping (NATMAP) in Australia. They are put into practice under the agreements for cooperation in science and technology between the two governments.

4. Launch of Ajisai

At 5:45 a.m. on 13th of August, 1986, JST, the first Japanese geodetic satellite was launched successfully from the Tanegashima Space Center by the National Space

Development Agency of Japan (NASDA) as a payload for the first test flight of newly developed H-I rocket . The satellite was named "Ajisai" immediately after the launch.
The announcement of the success of the launch by the NASDA and the speech of the president of NASDA in which the name of "Ajisai" first appeared are listed as Annex C.

The launch of this satellite had been requested to the Space Development Committee continuously for more than 15 years by the JHD and the Geographical Survey Institute (GSI), for their own uses. The JHD's intention was to use it for expanding the marine geodetic control network. In fact, Ajisai is destined to play the most important role in the project.

Ajisai was put into an orbit as scheduled beforehand quite exactly. In Table 2, the nominal Keplerian orbital elements and the actual ones are listed. The nominal ones are those scheduled before launch and the actual ones are those at the epoch, about 2 weeks after launch. The comparison of the both sets of elements shows how exact the launch was.

Also all the functions of Ajisai are proved to be perfect as the only geodetic satellite in the world the both distance and direction of which can be measured. Table 3 gives the functions of Ajisai, designed and actually confirmed by observations.

By October 6, 1986, the NASDA officially confirmed that all the functions stated above are normally operating, and on October 7, 1986, the operation of Ajisai was transferred from its initial phase to the regular one.

5. Establishment of Satellite Geodesy Office

Ajisai is to be used to determine the positions of the principal off-lying islands and the like. The observation and analysis concerning this satellite will occupy the biggest part in the project of establishing the marine geodetic control network. Moreover the JHD is responsible for the prediction of precise orbit of Ajisai necessary for the geodetic observations, according to the agreement among the NASDA, JHD and GSI.

In order to cope with these massive and quite new jobs, the Satellite Geodesy Office (SGO) was established in the Geodesy and Geophysics Division (GGD) of JHD on 5th of April, 1986. The new office started with 10 members including the Head.

The main services assigned to SGO were as follows:

a) Prediction of the orbit of Ajisai and its distribution,
b) Collection and Selection of observational data of Ajisai from the stations in the world,
c) Observation of Lageos and NNSS (this is the job which was continued from before the establishment of SGO), and
d) Management of the obtained data and their analysis.

To each above job accompanies the development of computer programs for each purpose. It should be noted that the above items are those officially authorized by the authorities. Actually a little flexible allocation of jobs is adopted.

On October 1 of the year the fixed number of the positions at the SHO was increased by one to strengthen the SLR observation so as to include Ajisai.

In 1987 fiscal year the increase of the fixed number of the positions both at the SGO and SHO was approved again. That is, on May 23, 1987, the members of SGO were increased from 10 to 16. The four of newly obtained six members are for engaging in the SLR and photographing observations on the islands, and the other two are for analyzing the data of Ajisai acquired on the islands and the SHO to get the accurate geodetic positions of the islands. And on October 1, 1987, two new members are to be added at the SHO on the pretext of letting them engage in the photographic observation of Ajisai.

As a powerful aid to the work at SGO other than personnels, the budget for introducing the satellite data reduction system was approved. The system will be rented from January 1, 1988.

Expansion of the services of SGO

The official accuracy of the determination of the positions of all the off-lying islands as well as the main land is about 1 meter. However, it is well known that a far better accuracy can be expected by the geodesy using SLR observation. The precision of the ranging to the satellites itself is considered to be several centimeters with the system at SHO. Newest systems in the world are said to have attained the precision even less than 1 cm.

Therefore, if we have a good software for data analysis it will be possible to determine the positions of the stations with the same accuracy. Then it enables to detect the plate motions or to observe crustal deformations. Keeping this in mind, the members in SGO have made efforts to develop a software to analyze very accurate coordinates of the station as well as the so-called Earth rotation parameters at the same time. The results of some simulations seem to promise a bright hope.

The Global Positioning System (GPS) can not be neglected when we consider the precise geodesy. According to the recent reports published numerously, a very high accuracy has been attained, for a short baseline at least. But it is very likely that the high accuracy will be possible for a longer baseline as well in the near future. To provide for such a day the SGO began the fundamental study on GPS as soon as its establishment. The study is carried out by participating in a study and research work of the Japan Hydrographic Association.

Recently, the Ministry of Transport is eager to develop its own multi-purpose satellites. Also the Maritime Safety Agency has begun the study on its services using artificial satellites. The SGO will have to play a positive role in these activities.

This article was prepared by Yoshio Kubo.

(This article is as of September 1, 1987.)

NASA
National Aeronautics and
Space Administration
Washington, D.C.
20546

LID-18

October 22, 1982

Dr. Kuniro Sugiura
Director General
Hydrographic Department
Maritime Safety Agency
3-1, Tsukiji 5-Chome
Chuo-Ku, Tokyo, 104
JAPAN

Dear Dr. Sugiura:

Technical discussions between NASA and the Hydrographic Department of Japan (JHD), Maritime Safety Agency have confirmed our mutual interest in initiating a joint project to: (1) conduct satellite laser tracking observations by stations in the U.S. and Japan and (2) to exchange laser tracking data and information concerning developments of geodynamics research software and hardware. This cooperation will contribute to the U.S. and Japan's expanding interest in applying space technology to geodynamics and geodesy and support further the global network of international geodynamics research activities. It is understood that this activity will be included as part of the NASA/Space Activities Commission of Japan cooperative program periodically reviewed and endorsed by the Senior Standing Liaison Group (SSLG).

In support of this cooperative activity, NASA, for its part, will use its best efforts to:

1. Provide Crustal Dynamics Project schedules for laser tracking operations;
2. Develop a detailed plan with the JHD for joint laser ranging experiments;
3. Conduct mutually agreed upon laser ranging operations in conjunction with Crustal Dynamics project Stations and other cooperating laser stations;
4. Provide orbit predictions and preprocessed and analyzed laser ranging data, which includes the data deposited in the Crustal Dynamics Data Bank upon request, in a mutually agreed upon format;
5. Provide NASA-developed software for use in the analysis of the laser tracking data and provide reports on the results of research activities conducted with laser ranging data, upon request;
6. Provide systems designs as currently used or contemplated in NASA laser systems and assist in the identification of commercial sources for components, as appropriate;
7. Make available, on a reimbursable basis, the assistance of NASA personnel for mutually agreed upon time periods to perform installation of software systems and training of Japanese personnel, as appropriate; and
8. Cooperate with investigators from Japan, Europe, South America, Australia, U.S. and other selected scientists to identify and develop a coordinated program aimed at the establishment of a global geodetic network involving fixed and mobile laser ranging systems to detect and monitor crustal and plate motions.

For its part, the Hydrographic Department of Japan (JHD) will use its best efforts to:

1. Provide Geodetic Network Project schedules for laser tracking operations;
2. Develop a detailed plan with NASA for joint laser ranging experiments;
3. Conduct mutually agreed upon laser tracking operations in conjunction with Crustal Dynamics Project stations and other cooperating laser stations;
4. Provide to NASA on a timely basis all Japanese acquired laser tracking data in a mutually agreed upon format;
5. Provide semi-annual reports on the results of research activities conducted with laser ranging data, including JHD-developed software for use in the processing and analysis of this data;
6. Provide reports on the development of laser systems in Japan, including systems designs as currently used or contemplated in Japanese laser ranging systems;

7. Cooperate with investigators from the U.S., Europe, South America, Australia and other selected scientists to identify and develop a coordinated program aimed at the establishment of a global geodetic network involving fixed and mobile laser ranging systems to detect and monitor crustal and plate motions; and
8. Arrange for participation by appropriate Japanese representatives in Crustal Dynamics Working Group meetings to be held twice yearly at Goddard Space Flight Center.

NASA is pleased to designate Dr. Edward A. Flinn, Chief Scientist, Geodynamics Program as the NASA point of contact for this project. We note that JHD has designated Dr. Akira Yamazaki, Director, Astronomical Division, JHD as the JHD point of contact.

It is understood that this project will be conducted with no exchange of funds between NASA and JHD and that each side will be responsible for funding its respective obligations, including travel and subsistance for its personnel and transportation for any materials for which it is responsible, except where noted above.

It is understood that the ability of NASA and JHD to carry out their obligations is subject to their respective funding procedures.

It is understood that the final report on this project will be made available to the general scientific community through publication in appropriate scientific journals and through other established channels. Copies of such publications will be made available to NASA and to JHD. In the event such publications or reports are copyrighted, JHD and NASA shall each have a royalty-free license under the copyright to use such publications for their own purposes.

The preprocessed and analyzed laser ranging data will be deposited in the Crustal Dynamic Data Bank at the Goddard Space Flight Center where it will be available to the international scientific community. Upon termination of NASA's Crustal Dynamics project, all data will be deposited in a permanent archiving facility.

It is further understood that NASA and JHD will use their best efforts to make available without restrictions on use current or contemplated software, reports on systems development and systems designs. In the event that it is agreed to exchange design or manufacturing information, such information will be exchanged under any protective conditions as agreed between the furnishing and receiving parties. If no protective conditions are stipulated by the furnishing Parties at the time of exchange, such additional information furnished is available without restrictions on its use. No rights are granted by this agreement to any present or future patents of the participating agencies and universities or their contractors, subcontractors or agents.

If the above terms and conditions are acceptable to the Hydrographic Department, we propose that this letter, together with your affirmative reply, constitute the agreed basis for proceeding with this cooperative project.

Sincerely,

(Signature)

Kenneth S. Pedersen
Director of International Affairs

HYDROGRAPHIC DEPARTMENT, MARITIME SAFETY AGENCY

3-1, TSUKIJI 5-CHOME, CHUO-KU, TOKYO, 104 JAPAN

H.D. 170/82 Dec. 6, 1982

Dr. K. S. Pedersen
Director of International Affairs
National Aeronautics and Space Administration
Washington, D.C. 20546
USA

Dear Dr. Pedersen:

With reference to your letter LID-18 dated October 22, 1982, the Hydrographic Department of Japan, Maritime Safety Agency (JHD) is pleased to confirm that it is prepared to initiate a joint project with NASA to conduct satellite laser tracking observations by stations in the U.S. and Japan and to exchange laser tracking data and information concerning developments of related software and hardware. This cooperation will contribute to the promotion of the study on geodesy and geodynamics in Japan and the U.S. It is understood that this activity will be included as part of the NASA/Space Activities Commission of Japan cooperative program periodically reviewed and endorsed by the Standing Senior Liaison Group (SSLG).

In support of this cooperative activity, JHD, for its part, will use its best efforts to:

1. Provide Geodetic Network Project schedules for laser tracking operations;
2. Develop a detailed plan with NASA for joint laser ranging experiments;
3. Conduct mutually agreed upon laser tracking operations in conjunction with Crustal Dynamics Project stations and other cooperating laser stations;
4. Provide to NASA on a timely basis Japanese acquired laser tracking data in a mutually agreed upon format;
5. Provide semi-anual reports on the results of research activities conducted with laser ranging data, including JHD-developed software for use in the processing and analysis of this data;
6. Provide reports on the development of laser systems in Japan, including systems designs as currently used or contemplated in Japanese laser ranging systems;
7. Cooperate with investigators from the U.S., Europe, South America, Australia, Japan and other selected scientists to identify and develop a coordinated program aimed at the establishment of a global geodetic network involving fixed and mobile laser ranging systems to detect and monitor crustal and plate motions; and
8. Arrange for participation by appropriate Japanese representatives in Crustal Dynamics Working Group meetings to be held twice yearly at Goddard Space Flight Center.

For its part, NASA will use its best efforts to:

1. Provide Crustal Dynamics Project schedules for laser tracking operations;
2. Develop a detailed plan with JHD for joint laser ranging experiments;
3. Conduct mutually agreed upon laser ranging operations in conjunction with Crustal Dynamics Project Stations and other cooperating laser stations;
4. Provide orbit predictions and preprocessed and analyzed laser ranging data, which includes the data deposited in the Crustal Dynamic Data Bank, upon request, in a mutually agreed upon format;
5. Provide NASA-developed software for use in the analysis of the laser tracking data, and provide reports on the results of research activities conducted with laser ranging data;
6. Provide system designs as currently used or contemplated in NASA laser systems and assist in the identification of commercial sources for components, as appropriate;
7. Make available, on a reimbursable basis, the assistance of NASA personnel for mutually agreed upon time periods to perform installation of software systems and training of Japanese personnel, as appropriate; and

8. Cooperate with investigators from Japan, Europe, South America, Australia, U.S. and other selected scientists to identify and develop a coordinated program aimed at the establishment of a global geodetic network involving fixed and mobile laser ranging systems to detect and monitor crustal and plate motions.

It is understood that this project will be conducted with no exchange of funds between JHD and NASA and that each side will be responsible for funding its respective obligations, including travel and subsistance for its personnel and transportation for any materials for which it is responsible, except where noted above.

It is understood that the ability of JHD and NASA to carry out their obligations is subject to their respective funding procedures.

It is understood that the final report on this project will be made available to the general scientific community through publication in appropriate scientific journals and through other established channel. Copies of such publications will be made available to JHD and NASA. In the event such publications or reports are copyrighted, JHD and NASA shall each have a royalty-free license under the copyright to use such publications for their own purposes.

It is understood that the preprocessed and analyzed laser ranging data will be deposited in the Crustal Dynamic Data Bank at the Goddard Space Flight Center where it will be available to the international scientific community. Upon termination of NASA's Crustal Dynamics project, all data will be deposited in a permanent archiving facility.

It is further understood that JHD and NASA will use their best efforts to make available without restrictions on use current or contemplated software, reports on systems development and systems designs. In the event that it is agreed to exchange design or manufacturing information, such information will be exchanged under any protective conditions as agreed between the furnishing and receiving parties. If no protective conditions are stipulated by the furnishing Parties at the time of exchange, such additional information furnished is available without restrictions on its use. No rights are granted by this agreement to any present or future patents of the participating agencies and universities or their contractors, subcontractors or agents.

JHD is pleased to designate Dr. Akira Yamazaki, Director, Astronomical Division, Hydrographic Department, Maritime Safety Agency as the JHD point of contact for this cooperative activities. We understand that your letter of October 22, 1982 and this reply constitute the agreed basis for proceeding with this cooperative project.

Truly yours,

(Signature)

Kuniro Sugiura
Director General

NASA

National Aeronautics and
Space Administration

Washington, D.C.
20546

LID

July 25, 1986

Dr. Takahiro Sato
Director General
Hydrographic Department
Maritime Safety Agency
3-1, Tsukiji 5-Chome
Chuo-Ku
Tokyo
104 JAPAN

Dear Dr. Sato:

Representatives between our two agencies have been discussing the technical feasibility of providing laser tracking support to the Japanese Geodetic Satellite (GS)/Experimental Geodetic Payload (EGP), to be launched in 1986. We have recently determined that it is technically feasible to provide laser tracking support from the NASA laser network, taking into consideration the existing NASA requirements. The tracking support that NASA will provide to the EGP builds upon and extends our ongoing cooperation on joint laser measurement campaigns for Geodynamics research utilizing the JHD Simosato Observatory, as part of the Space Activities Commission of Japan/NASA cooperative program periodically reviewed and endorsed by the Standing Senior Liaison Group (SSLG).

We would now like to propose the following arrangements for this activity.

NASA, for its part, will use its best efforts to fulfill the following responsibilities:

1. Develop a detailed plan with JHD for observations of GS/EGP, taken into account ongoing NASA laser tracking requirements;
2. Provide orbit predictions of GS/EGP to JHD in a mutually agreed upon format as jointly defined in the mission support plan;
3. Conduct mutually agreed upon observations of GS/EGP and provide to JHD the quick look range data and full observation data in a mutually agreed upon format;
4. Provide reports on the results of research activities conducted with applications of GS/EGP to JHD; and
5. Consult with JHD regarding the possibility of cooperating on future tracking activities involving NASA and JHD facilities and experiments to be defined in follow on arrangements.

The JHD, for its part, will use its best efforts to fulfill the following responsibilities.

1. Provide the necessary design information, upon request by NASA, of GS/EGP and the schedules of launching and observations of GS/EGP to NASA;
2. Provide orbit predictions of GS/EGP to NASA in a mutually agreed upon format as jointly defined in the mission support plan;
3. Provide the quick look range data and full observation data to NASA in a mutually agreed upon format;
4. Provide reports on the results of research activities conducted with observations of GS/EGP to NASA, upon request; and
5. Consult with NASA regarding the possibility of cooperating on future tracking activities involving NASA and JHD facilities and experiments to be defined in follow on arrangements.

NASA and the JHD will each bear the costs of discharging its respective responsibilities, including travel and subsistence of its own personnel and transportation of all equipment for which it is responsible.

Further, it is understood that the ability of NASA and the JHD to carry out their obligations is subject to their respective funding procedures.

Release of public information regarding this project may be made by the appropriate agency for its own portion of the program as desired and, insofar as participation of the other is involved, after suitable consultation.

It is the intent of the Parties that the exchange of technical information for the purpose of carrying out the objectives of this project will be accomplished without the involvement of restricted or proprietary information. In the event it is determined that the exchange of such restricted or proprietary information is necessary, the Parties agree to consult and provide for appropriate protective conditions for its exchange.

Results of the investigations will be made available to the scientific community in general through publication in appropriate journals or other established channels. In the event such reports or publications are copyrighted, the JHD and NASA shall have a royalty-free right under the copyright to reproduce and use such copyrighted work for their own purpose.

NASA and the JHD agree that this project is experimental in nature. Each side will use its best efforts to assure the successful completion of this activity. It is to be understood that NASA in no way warrants its tracking activities under this agreement.

NASA and the JHD will use their best efforts to arrange for free customs clearance of equipment required for this project.

NASA and the JHD agree to designate points-of-contact responsible for implementing the agreed upon activities. The NASA point-of-contact is:

Mr. John Bosworth
Goddard Space Flight Center
Code 601
Greenbelt, MD 20771

The JHD point-of-contact is:

Mr. Minoru Sasaki
Hydrographic Department
Maritime Safety Agency
3-1, Tsukiji 5-Chome
Chuo-ku
Tokyo
104 JAPAN

The JHD and NASA agree that should circumstances change that would affect each agency's ability to continue the project, a ninety day notice of intent to cease activities shall be submitted to the cooperating parties, without penalty to any party.

If the above terms and conditions are acceptable to the JHD, we propose that this letter, together with your affirmative reply, document our joint understanding as to the implementation of this cooperative effort.

Sincerely,

(Signature)

Richard J.H. Barnes
Director of International Affairs

HYDROGRAPHIC DEPARTMENT, MARITIME SAFETY AGENCY

3-1, TSUKIJI 5-CHOME, CHUO-KU, TOKYO, 104 JAPAN

August 1, 1986

Dr. Richard J.H. Barnes,
Director of International Affairs,
National Aeronautics and Space Administration,
Washington, D.C. 20546
USA

Dear Dr. Barnes:

It is our pleasure that the cooperation between the Hydrographic Department of Japan, Maritime Safety Agency (JHD) and the National Aeronautics and Space Administration (NASA) on the satellite laser tracking observations has been made successfully as part of the Space Activities Commission of Japan/NASA cooperative program periodically reviewed and endorsed by the Standing Senior Liaison Group (SSLG).

With reference to your letter dated July 25, 1986, JHD is pleased to confirm that it is prepared to extend our ongoing joint project with NASA to include satellite laser tracking observations of the Japanese Geodetic Satellite (GS)/Experimental Geodetic Payload (EGP), to be launched in 1986.

For this cooperative activity, JHD, for its part, will use its best efforts to fulfill the following responsibilities:

1. Provide the necessary design information, upon request by NASA, of GS/EGP and the schedules of launching and observations of GS/EGP to NASA;

2. Provide orbit predictions of GS/EGP to NASA in a mutually agreed upon format as jointly defined in the mission support plan;

3. Provide the quick look range data and full observation data to NASA in a mutually agreed upon format;

4. Provide reports on the results of research activities conducted with observations of GS/EGP to NASA, upon request; and

5. Consult with NASA regarding the possibility of cooperating on future tracking activities involving JHD and NASA facilities and experiments to be defined in follow on arrangements.

NASA, for its part, will use its best efforts to fulfill the following responsibilities:

1. Develop a detailed plan with JHD for observations of GS/EGP, taken into account ongoing NASA laser tracking requirements;

2. Provide orbit predictions of GS/EGP to JHD in a mutually agreed upon format as jointly defined in the mission support plan;

3. Conduct mutually agreed upon observations of GS/EGP and provide to JHD the quick look range data and full observation data in a mutually agreed upon format;

4. Provide reports on the results of research activities conducted with applications of GS/EGP to JHD; and

5. Consult with JHD regarding the possibility of cooperating on future tracking activities involving NASA and JHD facilities and experiments to be defined in follow on arrangements.

JHD and NASA will each bear the costs of discharging its respective responsibilities, including travel and subsistence of its own personnel and transportation of all equipment for which it is responsible.

Further, it is understood that the ability of JHD and NASA to carry out their obligations is subject to their respective funding procedures.

Release of public information regarding this project may be made by the appropriate agency for its own portion of the program as desired and, insofar as participation of the other is involved, after suitable consultation.

It is the intent of the Parties that the exchange of technical information for the purpose of carrying out the objectives of this project will be accomplished without the involvement of restricted or proprietary information. In the event it is determined that the exchange of such restricted or proprietary information is necessary, the Parties agree to consult and provide for appropriate protective conditions for its exchange.

Results of the investigations will be made available to the scientific community in general through publication in appropriate journals or other established channels. In the event such reports or publications are copyrighted, JHD and NASA shall have a royalty-free right under the copyright to reproduce and use such copyrighted work for their own purpose.

JHD and NASA agree that this project is experimental in nature. Each side will use its best efforts to assure the successful completion of this activity. It is to be understood that NASA in no way warrants its tracking activities under this agreement.

JHD and NASA will use their best efforts to arrange for free customs clearance of equipment required for this project.

JHD and NASA agree to designate points-of-contact responsible for implementing the agreed upon activities.

The JHD point-of-contact is:

Mr. Minoru Sasaki
Hydrographic Department
Maritime Safety Agency
3-1, Tsukiji 5-Chome
Chuo-ku
Tokyo, 104
JAPAN

The NASA point-of-contact is:

Mr. John Bosworth
Goddard Space Flight Center
Code 601
Greenbelt, MD 20771
USA

The JHD and NASA agree that should circumstances change that would affect each agency's ability to continue the project, a ninety day notice of intent to cease activities shall be submitted to the cooperating parties, without penalty to any party.

If the above terms and conditions are acceptable to NASA, we approve that your letter concerned and this affirmative reply document our joint understanding as to the implementation of this extended cooperation to be effective.

Sincerely,

(Signature)

Takahiro Sato
Director General

発　表　文

昭和61年8月13日
宇宙開発事業団
H-Ⅰロケット（2段式）試験機1号機打上げ隊

宇宙開発事業団は，昭和61年8月13日05時45分00秒（日本標準時）に，種子島宇宙センターからH-Ⅰロケット（2段式）試験機1号機を，発射方位角127度で打ち上げました。

第1段液体ロケット及び固体補助ロケットの燃焼は正常で，固体補助ロケットは発射後約1分28秒に，また，第1段ロケットは発射後約4分39秒に切り離しが行われ，これに引き続いて，第2段液体ロケットは，発射後約4分42秒の燃焼開始から発射後約10分13秒の燃焼停止までの間正常に燃焼し，誘導制御も正常に行われました。

引き続いて，第2段再着火も正常に行われ，計画どおり，発射後約59分21秒に第2段ロケットと測地実験機能部の，また発射後約62分07秒には第2段ロケットとアマチュア衛星の分離がそれぞれ行われました。

以上により，H-Ⅰロケット（2段式）試験機1号機は，予定したすべての飛行計画を終了しました。

打上げ実施に協力された関係各方面に深甚の謝意を表します。

本日，発射時の天候は西の風0.5m/s，気温24.9℃でした。

H-Ⅰロケット（2段式）試験機1号機の打上げについて

宇宙開発事業団は，本日午前5時45分 H-Ⅰロケット（2段式）試験機1号機を種子島宇宙センター大崎射場から打ち上げました。

ロケットは，正常に飛行し，技術開発の要である第2段液体酸素／液体水素推進系及び第2段慣性誘導装置も正常に働くとともに，第2段再着火も円滑に行われ，発射約59分後に第2段ロケットと測地実験機能部を，また発射約62分後には同じく第2段ロケットとアマチュア衛星をそれぞれ分離いたしました。

今後，磁気軸受フライホイールの機能及び軌道の確認並びに測地実験機能部の軌道確認等を行うこととしております。

なお，測地実験機能部は軌道投入後，測地実験衛星（愛称は，「あじさい」）と呼ぶこととしております。

今回のH-Ⅰロケットは，N-Ⅰ，N-Ⅱと進めてきた技術開発を基盤とし，第2段に自主開発による液体酸素／液体水素エンジンを採用するなど，その性能向上を図り，昭和60年代の衛星需要に応えることを目的としています。

H-Ⅰロケットの技術は，また大型衛星打上げ需要に対処するためのH-Ⅱロケット開発の礎となるものであり，本格的な宇宙開発の未来を拓くものであります。

職員一同，こうした重要な段階にのぞんでいることを深く自覚し，一層奮励努力する所存でございますので，今後ともよろしく御支援の程，お願い申し上げます。

また，この度のロケット打上げにおいて，地元はじめ関係者の皆様から賜りました多くの御協力に対し，心から御礼申し上げます。

昭和61年8月13日

宇宙開発事業団

理事長　大澤弘之

SATELLITE LASER RANGING OBSERVATIONS IN 1986

Summary – Satellite laser ranging observations have been continued at the Simosato Hydrographic Observatory. The total numbers of returns obtained at the observatory in 1986 are 147,526 from 224 passes of Lageos, 25,286 from 92 passes of Starlette, 15,359 from 56 passes of Beacon (BE)–C and 138,956 from 169 passes of Ajisai, respectively. The range precisions estimated by polynomial fitting to measured range minus predicted range (O–C) are 9.5 cm for Lageos, 10. 3 cm for Starlette, 10. 3 cm for BE–C and 9. 3 cm for Ajisai.

Key words: satellite laser ranging – global geodesy

This is a continuation of the report series of satellite laser ranging (SLR) observations made at the Simosato Hydrographic Observatory and contains the list of data obtained in 1986. Previous reports appear in Series of Astronomy and Geodesy, Data Report of Hydrographic Observations.

1. Observation

The routine ranging observations for Lageos, Starlette, and Beacon (BE)–C have been continued since April 1982 until July 1986 by using the SLR system at the Simosato Hydrographic Observatory under mutual cooperation between the Hydrographic Department (JHD) and the National Aeronautics and Space Administration (NASA) of the United States of America. According to the launch of Japanese first Geodetic Satellite "Ajisai" in August 1986, observations for BE–C was terminated. Lageos, Starlette and Ajisai are observed routinely since then.

The major specifications of the SLR system are listed in Table 1 (Sasaki *et al.*, 1983). The locations of the system and a fiducial stone marker set up near the system are shown in Table 2 (Takemura, 1983).

The observation schedule is made by selecting passes of maximum elevations of over 30 degrees of Lageos and Ajisai, over 40 degrees for daytime passes and over 45 degrees for night passes of Starlette and BE–C, except daytime of both Saturday afternoon and Sunday. The priority of the selection for simultaneous transits is in the order of Lageos, Starlette and BE–C until July and Ajisai, Lageos and Starlette since August.

The SAO-formatted orbital elements of the satellites for the use of scheduling and tracking are sent from Goddard Space Flight Center (GSFC) of NASA through telex. The orbital elements of Ajisai are also calculated in the Head Office of JHD by using quick-look data which are sent from GSFC via GE Mark III network. For the satellite tracking, an analytical tracking program using the elements are used. The tracking is carried out for elevation above 20 degrees. The atmospheric temperature, pressure and relative humidity are measured once in a pass. Before and after ranging to a satellite pass, the ranging calibration by using a ground target 1,415 m apart are made.

The total numbers of returns and passes observed at the Simosato Hydrographic Observatory in 1986 are listed in Table 3.

The micro-channel plate PMT (R-2024U No. 79) was replaced by a new one (No. 162) on March 27. This micro-channel plate (No. 162) was again exchanged to the older one (No. 79) on July 18 as the function of No. 79 was tested and no loss of sensitivity was found. Terminals for data communication network were installed at the Head Office and all the Hydrographic Observatories in the end of May. An additional view finder (14 cm aperture) was attached to the receiving telescope on July 16 in order to prepare for the observations of Ajisai. A remote controller of the telescope was set on July 18. An observer can track Ajisai by this controller pearing the view finder. The limits of the corrections applicable to the predicted azimuth and elevation by using a joystick were enlarged from 0.3 degree to 3 degrees by a software. Fortunately, neither the remote controller nor the enlarged limits of the joystick are used owing to good predictions of Ajisai.

2. Polynomial fitting and preliminary analysis of range data

The false range data are removed by visual rejection on a CRT screen and by applying the filter of polynomial fitting to measured range minus predicted range (O–C) in use of on-site computer. Preliminary values of measurement standard deviation for each pass are estimated in this process.

A part of range data, quick-look (QL) data, is sent to GSFC through telex within two days. All the range data, named full rate (FR) data, after applied correction of the internal delay time of the SLR system obtained by the ground target ranging, are recorded on a magnetic tape together with satellite ID, station ID, transmitted time corrected into UTC (USNO MC), meteorological data, preliminary measurement standard deviation, clock precision and some preprocessing indicators in the Seasat Decimal (SSD) Format (Schutz, 1983). The FR data on magnetic tapes for the four satellites are sent from the Simosato Hydrographic Observatory to the Head Office of JHD, GSFC and the Center for Space Research (CSR) of the University of Texas.

As for the polynomial fitting using on-site computer, only the polynomials from 1st to 9th order can be applicable owing to insufficient size of memory. Sometimes waving residuals of period of around 1 minute appear for low altitude satellites. It also became clear that many residuals of lower satellites contains wavings of shorter periods like 5–6 sec. To improve these situations polynomial fittings of the order from 1st to 20th are applied to all the range data by using ACOS 650 computer at the Head Office of JHD.

The weighted mean range precisions estimated by using the higher polynomial fitting for all the data obtained in 1986 are 9.5 cm for Lageos, 10. 3 cm for Starlette, 10. 3 cm for BE–C and 9. 3 cm for Ajisai as shown in Table 3 instead of 9.6 cm, 15.2 cm, 14.5 cm and 10.1 cm for the case of on-site fittings, respectively.

The QL data sent to GSFC are used to create new orbital elements. The data are transferred from GSFC to CSR and are used for estimation of the polar motion and variation of angular velocity of the earth rotation by processing with laser range data from other sites in the world. All the FR data are also analyzed in CSR and more precise values for earth rotation parameters have been estimated. The FR data sent to the Crustal Dynamics Project are used to detect crustal movements and intercontinental plate motions.

JHD has been processing a part of SLR data obtained at Simosato and other SLR sites by using an orbital processor (Sasaki, 1984a). A preliminary result of the geodetic coordinate for the cross point of azimuth and elevation axes of the SLR system at Simosato site, which is based on the longitude determined by the lunar laser ranging (LLR) observations at the McDonald Observatory, the University of Texas, is 33°34′39.″68N, 135°56′13.″35E, 100.9 m for latitude, longitude and hight above the reference ellipsoid of 6 378 137 m semi-major axis and 1/298.257 flattening, respectively (Sasaki, 1984b).

Calculations and compilation for this report have been made by T. Kanazawa, A. Sengoku and M. Nagaoka of JHD Head Office and E. Nishimura of the Simosato Hydrographic Observatory.

References

Abshire, J. B. 1980: *NASA Report*, "Plan for Investigating Atmospheric Errors in Satellite Laser Ranging Systems".

Marini, J. W., Murray Jr., C. W. 1973: *NASA Report*, X–591–73–351, GSFC, Maryland.

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Sasaki, M. 1984a: *Report of Hydrogr. Researches*, No. 19, p.107.

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Schutz, B. E. 1983: *Satellite Laser Ranging Procedures Guide for Project MERIT, CSR*, Univ. of Texas, Austin.

Takemura, T. 1983: *Data Report of Hydrogr. Obs., Series of Astronomy and Geodesy*, No. 17, p.44.

USNO 1986, 1987: *Daily Time Differences and Relative Phase Values, Series* 4, No. 988 – 1040.

The reports of the SLR observations for the preceding years were presented in the following numbers of the Data Report of Hydrographic Observations.

Sasaki, M., Nagaoka, M. 1984: *Data Report of Hydrogr. Obs., Series of Astronomy and Geodesy*, No. 18, p.55 (for 1982).

Sasaki, M., Sengoku, A., Nishimura, E., Nagaoka, M. 1985: *ibid.*, No. 19, p.50 (for 1983).

Sasaki, M., Sengoku, A., Nagaoka, M., Nishimura, E. 1986: *ibid.*, No. 20, p.44 (for 1984).

Kanazawa, T., Sengoku, A., Nagaoka, M., Nishimura, E. 1987: *ibid.*, No. 21, p.63 (for 1985).

Table 1. Principal specifications of the satellite laser ranging system at the Simosato Hydrographic Observatory

Mount configuration	elevation over azimuth
Angular resolution	20 bits (1.2 arcsec)
Transmitter diameter	17 cm
Receiver diameter	60 cm
Laser wave length	532 nm
Output energy	150 mJ (normal)
Laser pulse width	200 ps
Repetition rate	4 pps
Receiver detector	PMT (9% Q.E. and 300 ps rise time)
Flight time counter	20ps resolution
Frequency standard	Rubidium oscillator
Time comparison	multi-Loran C waves (NW Pacific Chain)
Computer	PDP 11/60 (64 kw) with two disk- and a MT drives

Table 2. Geodetic coordinates

Location	Site ID	Coordinates (Tokyo Datum)
Cross point of AZ. and EL. axes, the SLR system at Simosato Hydrogr. Obs.	International 7838 Domestic SHO–L	33° 34′ 27.″496 N 135 56 23.537 E 62.44 m
Cross line, the fiducial stone marker at Simosato Hydrogr. Obs.	Domestic SHO–H0	33° 34′ 28.″078 N 135 56 23.236 E 58.36 m

Table 3. Data acquisition at the Simosato Hydrographic Observatory in 1986

Satellite	No. of ranges	No. of passes	RMS deviation
Lageos	147,526	224	9.5 cm
Starlette	25,286	92	10.3
BE–C	15,359	56	10.3
Ajisai	138,956	169	9.3

Observers E. Nishimura, K. Matsumoto, K. Koyama, H. Sasaki, A. Masuyama, M. Sawa, M. Naka, M. Nagaoka*

* temporary support from JHD Head Office

Table 4. Observations and data fitting

Explanation

Column

1, 8 Serial number of passes ranged successfully for each satellite.

2 Observation time (UTC) of the first return and the last return observed in the satellite pass.

3 Satellite identification (ID), LG: Lageos, ST: Starlette, BC: BE–C, AJ: Ajisai.

4 Azimuth when the tracking of the satellite started at 20° of elevation.

5 Elevations at the maximum, at the first return obtained and at the last return obtained in the satellite path. U means through the maximum elevation.

6 Number of successful returns from the satellite in the pass.

7 Order of the polynomials applied and the root mean square deviation of the curve fitting to measured range minus predicted range. Before the fitting applied an atmospheric correction (Marini and Murray, 1973) is added.

The range correction added to the measured range is

$$dR = \frac{g(\lambda)}{f(\varphi, H)} \cdot \frac{A + B}{\sin E + \dfrac{B/(A+B)}{\sin E + 0.01}},$$

where

$$g(\lambda) = 0.9650 + \frac{0.0164}{\lambda^2} + \frac{0.000228}{\lambda^4},$$

$$f(\varphi, H) = 1 - 0.0026 \cos 2\varphi - 0.00031\, H,$$

$$A = 0.002357\, P + 0.000141\, e,$$

$$B = (1.084 \times 10^{-8})\, PTK + (4.734 \times 10^{-8})\, \frac{P^2}{T} \cdot \frac{2}{(3 - 1/K)},$$

$$K = 1.163 - 0.00968 \cos 2\varphi - 0.00104\, T + 0.00001435\, P,$$

$$e = 6.11 \cdot \frac{Rh}{100} \cdot 10^{7.5(T-273.15)/\{237.3+(T-273.15)\}}$$

Here

dR : Range correction (meters),

E : True elevation of satellite,

P : Atmospheric pressure at the site (millibars),

T : Atmospheric temperature at the site (degrees Kelvin),

Rh : Relative humidity at the site (%),

λ : Wavelength of the laser (microns),

φ : Latitude of the site,

H : Altitude of the site (kilometers).

This term is not corrected for the measured range in the final MT file.

9 Station ID, 7838: Simosato Hydrographic Observatory.

Column

10 Atmospheric temperature (degrees Centigrade).

11 Atmospheric pressure (millibars).

12 Relative humidity (%).

13 Calibrated internal delay time of the SLR system obtained by the ground target ranging. The light velocity change in the air (Abshire, 1980) is used for the atmospheric correction. This term is corrected for the range data in the final MT file.

The group velocity of light in the air is given by

$$v = c \cdot (1 + 10^{-6} N)^{-1},$$

where

$$N = 80.343\,(0.9650 + \frac{0.0164}{\lambda^2} + \frac{0.00028}{\lambda^4})\frac{P}{T} - 11.3\frac{e}{T},$$

$$e = 6.11 \cdot \frac{Rh}{100} \cdot 10^{7.5(T-273.15)/\{237.3+(T-273.15)\}}.$$

Here

c : The vacuum speed of light,

P : Atmospheric pressure (millibars),

T : Atmospheric temperature (degrees Kelvin),

Rh : Relative humidity (%),

λ : Wavelength of the light (microns).

14 Time correction: Transmitting time of the Loran C North West Pacific (997) Chain minus time of the clock used in the SLR system. This term is corrected for the transmitted time in the final MT file.

15 Time correction: UTC (USNO MC) minus transmitting time of the Loran C North West Pacific (997) Chain (USNO, 1986, 1987). This term is corrected for the transmitted time in the final MT file.

16 Comments.

Table 4. Observations and data evaluation

(1) No.	(2) Obs.Time(UTC) date	caught	lost	(3) SAT.	(4)Az. ST	(5)Elev. MX	CT	LT	(6) RTN	(7)Fitting N	RMS
	Y M D	h m s	h m s		°	°	°	°			cm
1	86 01 04	08 40 37	09 20 56	LG	20L	60	26U	21	748	7	9.6
2	86 01 04	15 29 16	15 48 22	LG	105L	50	39U	42	107	5	7.6
3	86 01 04	18 52 18	19 33 05	LG	-180R	55	29U	20	623	7	9.8
4	86 01 05	18 02 19	18 09 41	LG	-210R	85	43	25	139	5	8.0
5	86 01 06	06 10 07	06 28 32	LG	36R	60	55U	44	393	7	9.3
6	86 01 06	09 28 03	09 59 28	LG	20L	45	22U	30	422	7	9.6
7	86 01 06	16 08 54	16 34 39	LG	120L	65	32U	53	559	7	10.3
8	86 01 07	14 50 07	15 25 57	LG	90L	45	25U	20	473	7	9.7
9	86 01 08	06 50 07	07 02 51	LG	25R	80	42	80	233	5	6.6
10	86 01 08	10 24 50	10 47 39	LG	15L	35	31U	20	107	5	10.0
11	86 01 08	17 00 46	17 30 04	LG	140L	85	48U	38	53	5	10.9
12	86 01 09	05 24 56	05 52 27	LG	40R	50	29U	42	115	5	8.0
13	86 01 09	08 53 16	09 27 33	LG	20L	50	22U	32	696	7	8.7
14	86 01 09	15 33 40	16 13 34	LG	115L	55	26U	22	779	7	8.3
15	86 01 09	19 24 24	19 34 59	LG	-170R	45	45	36	99	5	9.8
16	86 01 10	07 50 43	08 12 56	LG	25L	75	74U	27	235	5	8.3
17	86 01 10	14 17 24	14 51 37	LG	80L	38	22U	20	302	7	8.6
18	86 01 10	17 39 08	18 11 18	LG	-200R	75	24U	55	590	9	11.1
19	86 01 11	09 41 56	10 15 16	LG	20L	40	21U	22	397	7	9.4
20	86 01 11	16 19 04	17 03 31	LG	130L	75	26U	20	575	7	9.0
21	86 01 12	08 35 25	08 58 10	LG	20L	60	55U	27	262	7	7.7
22	86 01 12	15 11 20	15 40 18	LG	105L	50	42U	20	282	7	9.9
23	86 01 12	18 30 18	18 48 22	LG	-180R	55	25	54	325	5	11.2
24	86 01 13	17 06 40	17 50 16	LG	-210R	85	28U	24	717	7	9.7
25	86 01 14	09 11 25	09 39 18	LG	20L	45	28U	30	399	7	12.2
26	86 01 14	15 50 57	16 28 13	LG	120L	65	37U	22	884	7	11.1
27	86 01 16	16 41 36	17 17 48	LG	140L	85	50U	20	1022	9	9.7
28	86 01 17	15 12 45	15 54 50	LG	115L	55	24U	20	539	7	8.8
29	86 01 17	18 45 22	19 17 21	LG	-170R	45	23U	33	663	7	9.3
30	86 01 20	18 10 27	18 46 00	LG	-180R	55	25U	33	989	7	9.8
31	86 01 22	08 51 05	09 20 27	LG	20L	45	27U	28	281	7	9.8
32	86 01 22	15 44 50	15 57 36	LG	125L	65	65U	46	124	7	10.4
33	86 01 23	07 46 16	07 50 41	LG	20L	70	66U	62	137	5	10.3
34	86 01 23	14 12 49	14 45 56	LG	90L	45	29U	20	576	7	8.5
35	86 01 23	17 33 24	18 10 31	LG	-190R	65	22U	39	1170	9	10.8
36	86 01 24	06 03 40	06 21 32	LG	25R	80	26	76	61	5	8.2
37	86 01 24	09 36 34	10 01 33	LG	15L	35	22U	28	375	7	7.8
38	86 01 24	16 10 29	16 58 01	LG	140L	85	22U	20	369	7	8.8
39	86 01 25	14 51 55	15 34 04	LG	115L	55	22U	22	1311	9	9.3
40	86 01 25	18 25 11	19 05 49	LG	-170R	45	22U	20	678	7	10.3
41	86 01 27	09 05 17	09 26 09	LG	20L	38	26U	35	165	7	11.4
42	86 01 27	15 40 42	15 54 12	LG	125L	75	30U	65	148	5	9.2
43	86 01 28	14 24 33	14 59 35	LG	105L	50	30U	22	246	7	9.7
44	86 01 28	17 52 22	18 22 52	LG	-180R	55	29U	39	453	7	9.6
45	86 01 29	13 22 59	13 32 25	LG	70L	35	34	27	61	5	9.4
46	86 01 29	16 44 06	17 11 08	LG	-210R	85	77U	22	81	5	11.5
47	86 01 31	17 19 06	17 56 45	LG	-190R	60	34U	26	299	7	10.5
48	86 02 02	14 47 08	15 11 50	LG	115L	55	52U	26	323	7	8.0
49	86 02 02	18 04 56	18 38 36	LG	-170R	45	21U	31	525	7	11.9
50	86 02 03	13 18 12	13 42 14	LG	85L	38	23U	33	100	5	9.0
51	86 02 03	16 44 41	17 22 33	LG	-200R	75	36U	27	959	7	9.7
52	86 02 04	05 21 22	05 26 47	LG	30R	75	54	68	69	5	10.4
53	86 02 04	15 21 29	15 58 05	LG	135L	75	32U	33	1005	7	10.4
54	86 02 05	07 38 54	07 42 30	LG	20L	60	57U	56	65	5	8.0
55	86 02 06	16 07 22	16 49 50	LG	-210R	80	29U	25	416	7	9.1
56	86 02 08	13 43 12	14 05 45	LG	95L	45	43U	21	323	7	13.0
57	86 02 08	16 58 20	17 39 48	LG	-190R	65	32U	20	832	7	10.3
58	86 02 09	15 31 25	16 18 02	LG	140L	85	24U	20	1125	9	9.6
59	86 02 10	14 14 11	14 27 53	LG	115L	55	26	53	97	5	14.5
60	86 02 11	13 03 18	13 28 45	LG	85L	40	30U	25	371	7	11.8

Table 4. Observations and data evaluation

(8) No.	(9) STN	(10) TMP	(11) PRESS	(12) HUM	(13) IDT	(14) DTS	(15) DTL	(16) COMMENTS
		°C	mb	%	ns	µs	µs	
1	7838	6.5	998.6	68	7.4	-0.2	-0.7	
2	7838	2.6	997.3	73	7.2	-0.5	-0.7	
3	7838	1.5	998.1	64	7.4	-0.5	-0.7	
4	7838	-0.9	1004.0	83	7.6	-0.7	-0.7	
5	7838	5.0	1006.4	30	7.5	-0.5	-0.7	DAYTIME
6	7838	1.0	1010.4	49	7.6	-0.6	-0.7	
7	7838	-0.2	1010.8	69	7.5	-0.5	-0.7	
8	7838	2.6	1008.0	80	7.6	-0.3	-0.7	
9	7838	10.6	1004.7	73	7.4	-0.7	-0.7	DAYTIME
10	7838	4.9	1008.0	56	7.4	-0.5	-0.7	
11	7838	1.8	1010.5	79	7.4	-0.6	-0.7	
12	7838	5.9	1012.8	33	7.6	-0.4	-0.7	DAYTIME
13	7838	2.4	1014.1	44	7.5	-0.5	-0.7	
14	7838	0.6	1015.6	53	7.5	-0.5	-0.7	
15	7838	0.0	1015.2	50	7.5	-0.6	-0.7	
16	7838	3.1	1014.1	52	7.6	-0.4	-0.7	DAYTIME
17	7838	0.7	1014.5	45	7.6	-0.6	-0.7	
18	7838	-0.3	1015.4	57	7.8	-0.7	-0.7	
19	7838	2.7	1016.9	55	7.6	-0.3	-0.7	
20	7838	-0.5	1017.5	75	7.6	-0.4	-0.7	
21	7838	3.7	1017.8	38	7.6	-0.4	-0.7	
22	7838	1.3	1014.9	61	7.4	-0.8	-0.7	
23	7838	1.8	1013.6	66	7.7	-0.5	-0.7	
24	7838	2.0	1008.6	52	7.6	-0.2	-0.8	
25	7838	4.5	1009.9	55	7.5	-0.4	-0.8	
26	7838	1.0	1010.6	74	7.3	-0.7	-0.8	
27	7838	6.6	1006.2	63	7.4	-0.8	-0.9	
28	7838	2.4	1011.4	76	7.3	-0.1	-0.9	
29	7838	2.7	1010.6	68	7.2	-0.4	-0.9	
30	7838	7.1	1007.1	81	7.2	-0.3	-0.9	
31	7838	3.8	1000.3	74	7.3	-0.6	-0.9	
32	7838	1.1	1003.4	87	7.5	-0.7	-0.9	
33	7838	5.7	1004.0	50	7.4	-0.4	-1.0	DAYTIME
34	7838	1.8	1006.4	70	7.4	-0.5	-1.0	
35	7838	3.7	1006.9	52	7.4	-0.3	-1.0	
36	7838	9.9	1006.6	37	7.2	-0.7	-1.0	DAYTIME
37	7838	5.0	1010.0	52	7.2	-0.3	-1.0	
38	7838	3.3	1012.1	56	7.8	-0.4	-1.0	
39	7838	2.0	1009.9	67	7.1	-0.7	-0.9	
40	7838	0.3	1009.9	66	7.0	-0.9	-0.9	
41	7838	2.1	1011.4	58	7.3	-0.5	-0.9	
42	7838	-1.3	1011.9	71	7.5	-0.7	-0.9	
43	7838	1.0	1013.8	68	7.2	-1.0	-0.9	
44	7838	0.6	1014.5	66	7.3	-0.5	-0.9	
45	7838	4.1	1013.8	60	7.0	-0.6	-0.9	
46	7838	1.6	1013.0	76	7.4	-0.6	-0.9	
47	7838	4.7	1006.6	62	7.2	0.0	-0.8	
48	7838	2.2	1009.0	65	7.0	-0.4	-0.8	
49	7838	3.4	1007.7	62	7.3	-0.3	-0.8	
50	7838	4.1	1007.7	53	7.3	-0.8	-0.7	
51	7838	2.1	1008.2	40	7.2	-0.7	-0.7	
52	7838	7.2	1007.1	39	7.4	-0.4	-0.7	DAYTIME
53	7838	1.1	1011.4	48	7.4	-0.6	-0.7	
54	7838	7.3	1008.4	38	7.3	-0.4	-0.7	DAYTIME
55	7838	0.2	1009.1	61	7.7	-0.9	-0.7	
56	7838	-0.5	1012.5	72	7.1	-0.9	-0.8	
57	7838	-0.5	1013.3	67	7.4	-0.9	-0.8	
58	7838	-0.2	1014.7	67	7.4	-0.4	-0.7	
59	7838	0.4	1011.5	67	7.3	-0.8	-0.7	
60	7838	2.3	1005.7	49	7.2	-1.3	-0.7	

Table 4. Observations and data evaluation

(1) No.	(2) Obs.Time(UTC) date	caught	lost	(3) SAT.	(4)Az. ST	(5)Elev. MX	CT	LT	(6) RTN	(7)Fitting N	RMS
	Y M D	h m s	h m s		°	°	°	°			cm
61	86 02 11	16 21 24	17 06 06	LG	-200R	75	28U	20	1014	9	10.5
62	86 02 12	15 04 42	15 43 20	LG	135L	75	40U	21	1024	9	9.6
63	86 02 13	17 25 32	17 52 46	LG	-180R	55	51U	21	389	5	8.3
64	86 02 16	13 10 55	13 45 37	LG	95L	45	26U	21	221	7	11.8
65	86 02 16	16 34 06	17 13 24	LG	-190R	65	23U	33	1286	9	9.7
66	86 02 17	15 13 45	15 33 09	LG	145L	85	29	84	216	5	9.7
67	86 02 19	12 43 51	13 11 20	LG	85L	38	31U	21	304	5	9.4
68	86 02 19	16 03 36	16 45 47	LG	-200R	75	33U	21	842	9	10.4
69	86 02 20	14 42 21	15 23 49	LG	135L	75	34U	20	996	9	10.0
70	86 02 21	13 24 50	13 48 24	LG	105L	50	31U	43	327	7	9.4
71	86 02 21	16 57 39	17 31 40	LG	-180R	55	38U	23	832	9	9.7
72	86 02 22	15 25 32	16 12 15	LG	-210R	85	25U	20	1854	9	7.5
73	86 02 23	14 11 06	14 49 35	LG	125L	65	40U	20	1458	9	9.7
74	86 02 24	12 54 45	13 25 16	LG	95L	45	32U	22	665	7	9.2
75	86 02 24	16 12 57	16 59 29	LG	-190R	65	21U	21	908	9	9.8
76	86 02 25	14 51 02	15 37 25	LG	145L	85	23U	22	1623	9	8.0
77	86 02 27	12 19 21	12 51 48	LG	85L	40	25U	20	629	7	9.4
78	86 02 27	15 38 16	16 26 12	LG	-200R	75	21U	20	1967	9	9.9
79	86 02 28	14 16 47	15 03 54	LG	135L	75	21U	20	2253	9	9.9
80	86 03 02	15 03 51	15 52 13	LG	-210R	85	21U	20	2576	9	8.5
81	86 03 03	13 44 27	14 28 24	LG	125L	65	22U	22	903	9	9.7
82	86 03 04	12 35 52	12 58 10	LG	95L	45	34U	34	139	7	9.2
83	86 03 04	15 54 25	16 29 59	LG	-190R	65	24U	40	1656	7	9.5
84	86 03 05	14 30 58	15 16 52	LG	145L	85	23U	23	1443	9	9.3
85	86 03 06	13 20 37	13 54 18	LG	115L	55	40U	22	276	7	9.3
86	86 03 06	16 46 10	17 24 45	LG	-165R	45	23U	22	570	9	8.5
87	86 03 07	12 06 45	12 31 49	LG	85L	38	35U	20	347	7	7.8
88	86 03 07	15 29 58	16 05 17	LG	-200R	75	49U	22	768	9	9.6
89	86 03 08	14 09 34	14 43 19	LG	135L	75	52U	21	497	7	7.7
90	86 03 10	15 09 25	15 21 14	LG	-205R	85	82	47	174	5	8.6
91	86 03 11	13 36 04	14 09 43	LG	125L	65	49U	20	2348	9	9.3
92	86 03 12	12 08 31	12 45 35	LG	95L	45	22U	21	456	7	8.1
93	86 03 12	15 44 56	16 19 55	LG	-190R	60	46U	20	913	7	8.2
94	86 03 15	15 08 04	15 45 55	LG	-200R	70	44U	21	852	7	8.2
95	86 03 17	12 19 31	13 00 42	LG	105L	50	21U	20	1549	9	7.8
96	86 03 17	15 55 35	16 32 32	LG	-175R	50	34U	21	1222	9	7.4
97	86 03 20	11 49 07	12 26 18	LG	95L	45	23U	20	1045	7	8.5
98	86 03 20	15 17 45	15 58 40	LG	-190R	60	30U	22	2031	7	7.9
99	86 03 21	13 56 00	14 37 42	LG	145L	85	34U	21	2029	9	8.5
100	86 03 23	14 39 33	15 25 59	LG	-200R	70	23U	21	2497	9	8.6
101	86 03 24	13 28 23	13 55 18	LG	135L	75	49U	40	682	9	12.1
102	86 03 25	12 14 19	12 36 42	LG	105L	50	47U	28	954	9	8.9
103	86 03 25	15 29 13	16 10 02	LG	-175R	50	22U	26	1106	9	9.1
104	86 03 29	13 31 16	14 04 54	LG	145L	85	23U	54	702	9	8.8
105	86 03 31	11 02 10	11 19 18	LG	85L	40	29	37	427	7	8.6
106	86 03 31	14 41 48	15 02 54	LG	-200R	75	73U	27	224	5	8.8
107	86 04 01	12 58 19	13 36 20	LG	135L	75	24U	38	935	9	10.5
108	86 04 02	11 46 01	12 13 07	LG	105L	50	33U	35	68	5	8.2
109	86 04 05	11 16 44	11 38 41	LG	95L	45	36U	34	591	9	11.3
110	86 04 05	14 34 59	15 19 59	LG	-190R	60	24U	20	2029	9	10.3
111	86 04 07	11 57 23	12 31 10	LG	115L	60	33U	29	721	9	9.2
112	86 04 07	15 26 13	16 05 47	LG	-165R	40	22U	20	561	7	10.6
113	86 04 10	11 23 15	11 52 10	LG	105L	50	28U	37	254	7	9.3
114	86 04 10	14 49 18	15 31 00	LG	-175R	50	21U	24	1015	9	8.2
115	86 04 11	13 32 27	14 12 31	LG	-205R	80	41U	20	544	7	8.8
116	86 04 12	02 06 36	02 09 05	LG	35R	65	48	54	24	5	10.5
117	86 04 12	12 08 03	12 48 54	LG	125L	65	30U	22	1316	7	10.0
118	86 04 13	14 29 40	14 42 18	LG	-190R	60	55	56	45	7	10.7
119	86 04 16	10 20 04	10 51 25	LG	85L	40	26U	21	628	7	10.1
120	86 04 16	13 58 00	14 17 11	LG	-195R	70	68U	41	320	9	10.8

Table 4. Observations and data evaluation

(8) No.	(9) STN	(10) TMP	(11) PRESS	(12) HUM	(13) IDT	(14) DTS	(15) DTL	(16) COMMENTS
		°C	mb	%	ns	μs	μs	
61	7838	2.5	1006.9	46	7.4	-1.5	-0.7	
62	7838	2.9	1013.0	52	7.2	-1.0	-0.7	
63	7838	8.8	1006.6	48	7.5	-0.3	-0.6	
64	7838	0.3	1016.0	38	7.3	-0.4	-0.6	
65	7838	-0.2	1015.8	45	7.5	0.0	-0.6	
66	7838	2.4	1014.4	64	7.2	-0.3	-0.5	
67	7838	4.0	1008.2	58	7.2	-0.2	-0.5	
68	7838	0.9	1009.7	75	7.5	-0.7	-0.5	
69	7838	3.8	1005.3	59	7.1	-0.7	-0.4	
70	7838	1.3	1008.0	58	7.5	-0.3	-0.4	
71	7838	1.1	1007.5	67	7.6	-0.5	-0.4	
72	7838	1.0	1006.9	63	7.5	-0.4	-0.3	
73	7838	5.0	1004.2	41	7.5	-0.2	-0.2	
74	7838	1.1	1008.6	46	7.6	-0.5	-0.2	
75	7838	-1.2	1009.6	64	7.7	-0.5	-0.2	
76	7838	-1.6	1013.6	61	7.6	-0.5	-0.2	
77	7838	3.4	1004.0	54	7.5	-0.7	-0.2	
78	7838	2.0	1004.2	40	7.6	-0.4	-0.2	
79	7838	2.2	1008.2	53	7.5	-0.2	-0.2	
80	7838	2.6	1003.9	56	7.5	-0.6	-0.4	
81	7838	4.1	1009.3	51	7.6	-0.3	-0.4	
82	7838	3.3	1011.0	61	7.5	-0.6	-0.5	
83	7838	1.6	1009.7	67	7.6	-0.4	-0.5	
84	7838	3.3	1013.0	38	7.3	-0.5	-0.7	
85	7838	4.7	1018.2	74	7.3	-0.5	-0.8	
86	7838	5.4	1018.2	77	7.7	-0.5	-0.8	
87	7838	6.9	1017.5	89	7.4	-0.7	-1.0	
88	7838	6.8	1017.8	82	7.6	-0.5	-1.0	
89	7838	6.8	1020.4	80	7.6	-0.4	-1.1	
90	7838	11.0	1009.0	95	7.5	-0.2	-1.2	
91	7838	9.6	1002.1	68	7.4	-0.4	-1.3	
92	7838	5.8	1014.3	65	7.6	-0.4	-1.3	
93	7838	5.0	1014.7	78	7.6	-0.4	-1.3	
94	7838	8.6	1001.6	90	7.6	-0.4	-1.4	
95	7838	5.7	1009.1	41	7.7	-0.6	-1.5	
96	7838	3.8	1008.2	40	7.6	-0.9	-1.5	
97	7838	5.9	1008.1	58	7.5	-0.4	-1.5	
98	7838	2.8	1008.4	71	7.6	-0.4	-1.5	
99	7838	5.5	1010.0	70	7.5	-0.6	-1.4	
100	7838	5.7	997.3	52	7.4	-0.5	-1.3	
101	7838	3.3	1010.8	45	6.8	-0.3	-1.3	
102	7838	5.0	1018.0	51	7.3	-0.5	-1.3	
103	7838	3.4	1018.2	63	7.4	-0.5	-1.3	
104	7838	10.0	1005.8	90	7.6	-0.5	-1.7	
105	7838	9.8	1008.4	35	7.6	-0.4	-1.7	
106	7838	7.7	1009.7	42	7.4	-0.5	-1.7	
107	7838	6.2	1011.7	76	7.5	-0.7	-1.8	
108	7838	9.7	1015.6	60	7.6	-0.3	-1.8	
109	7838	12.0	1008.0	54	7.6	-0.2	-1.8	
110	7838	8.8	1009.3	64	7.6	-0.2	-1.8	
111	7838	4.0	1018.6	65	7.5	-0.4	-1.7	
112	7838	3.8	1019.7	57	7.5	-0.4	-1.7	
113	7838	17.4	1003.2	98	7.4	0.0	-1.7	
114	7838	17.2	1002.3	95	7.5	-0.1	-1.7	
115	7838	9.3	1006.6	55	7.5	-0.6	-1.7	
116	7838	12.8	1011.7	33	7.2	-0.6	-1.7	DAYTIME
117	7838	9.8	1013.6	47	7.3	-0.4	-1.7	
118	7838	9.6	1017.3	76	7.4	-0.6	-1.7	
119	7838	11.0	1008.6	60	7.7	-0.2	-1.7	
120	7838	9.5	1010.4	65	7.5	-0.2	-1.7	

Table 4. Observations and data evaluation

(1) No.	(2) Obs.Time(UTC) date	caught	lost	(3) SAT.	(4)Az. ST	(5)Elev. MX	CT	LT	(6) RTN	(7)Fitting N	RMS
	Y M D	h m s	h m s		°	°	°	°			cm
121	86 04 23	14 46 34	15 24 25	LG	-165R	40	22U	22	745	9	9.1
122	86 04 24	10 02 29	10 26 52	LG	85L	40	30U	28	377	7	10.3
123	86 04 24	13 20 02	14 00 07	LG	-195R	70	24U	34	1513	9	9.5
124	86 04 25	12 02 38	12 36 39	LG	135L	75	34U	37	1301	9	7.4
125	86 04 29	13 39 34	14 05 24	LG	-185R	60	33U	50	1013	9	7.4
126	86 05 06	11 20 28	11 49 57	LG	125L	70	59U	20	941	9	8.5
127	86 05 07	10 03 44	10 26 07	LG	95L	45	44U	21	282	7	9.1
128	86 05 07	13 14 37	13 53 10	LG	-185R	60	23U	34	973	9	7.9
129	86 05 09	10 38 11	11 14 37	LG	115L	60	35U	22	894	9	10.1
130	86 05 09	14 21 43	14 34 32	LG	-165R	45	41U	36	55	7	12.6
131	86 05 12	10 10 03	10 30 46	LG	105L	50	41U	40	515	7	10.8
132	86 05 12	13 32 15	13 56 25	LG	-175R	50	26U	48	397	9	12.0
133	86 05 15	12 57 31	13 40 08	LG	-185R	60	28U	20	970	9	10.7
134	86 05 16	11 31 32	12 18 35	LG	145L	85	23U	20	1775	9	9.1
135	86 05 17	10 15 11	10 55 42	LG	115L	60	28U	20	1431	9	8.3
136	86 05 17	13 46 51	14 26 01	LG	-165R	40	22U	20	1053	9	8.9
137	86 05 23	12 39 42	13 20 05	LG	-185R	60	33U	20	549	9	10.0
138	86 05 31	12 18 55	12 37 29	LG	-185R	60	31	60	99	5	12.7
139	86 06 08	12 07 11	12 37 23	LG	-185R	60	48U	26	534	7	14.2
140	86 06 09	10 33 58	11 14 46	LG	145L	85	29U	29	865	9	11.7
141	86 06 11	11 40 37	11 58 49	LG	-195R	70	70U	37	242	7	11.5
142	86 06 19	11 03 38	11 40 59	LG	-195R	70	31U	32	929	9	10.2
143	86 06 26	12 09 02	12 45 05	LG	-165R	40	24U	21	359	9	12.9
144	86 07 31	00 12 33	00 27 39	LG	20L	55	46U	47	103	5	7.5
145	86 07 31	10 19 37	10 49 35	LG	-175R	50	37U	27	864	9	9.3
146	86 07 31	22 46 01	22 54 33	LG	25L	80	44	69	66	5	10.0
147	86 08 05	00 32 06	00 39 49	LG	20L	50	47	43	116	5	9.5
148	86 08 05	10 28 57	11 05 19	LG	-160R	40	23U	21	460	7	9.5
149	86 08 05	23 02 55	23 28 32	LG	20L	70	50	38	281	7	8.7
150	86 08 08	22 34 20	22 57 53	LG	25L	80	68U	33	152	7	8.7
151	86 08 13	10 21 30	10 26 19	LG	-160R	40	38	39	69	5	10.3
152	86 08 14	05 21 33	05 46 43	LG	90L	40	29U	30	357	7	8.7
153	86 08 18	19 24 34	19 41 34	LG	50R	40	33U	36	65	5	8.1
154	86 08 19	21 31 11	21 57 36	LG	25L	85	42U	51	427	7	8.5
155	86 08 29	22 09 45	22 20 47	LG	20L	70	66U	58	359	5	9.4
156	86 08 31	19 24 01	19 46 36	LG	40R	50	46U	27	446	7	10.1
157	86 09 03	18 44 10	19 03 28	LG	45R	40	32U	34	191	7	10.8
158	86 09 05	19 34 03	20 00 30	LG	35R	60	47U	31	739	7	8.8
159	86 09 11	06 11 01	06 14 13	LG	130L	70	67	60	38	3	10.3
160	86 09 21	18 51 13	19 26 18	LG	35R	60	41U	20	1871	9	8.8
161	86 09 22	05 16 38	05 34 46	LG	110L	65	61	23	261	7	10.0
162	86 09 24	18 10 23	18 29 04	LG	40R	50	25	49	260	7	7.7
163	86 09 24	21 50 56	22 12 54	LG	20L	50	42U	37	193	5	10.1
164	86 09 25	04 28 53	04 42 08	LG	110L	55	40	54	128	5	10.8
165	86 09 25	20 18 16	20 52 33	LG	25L	80	24U	47	782	9	9.0
166	86 09 28	19 46 33	20 25 49	LG	25L	85	30U	29	1530	9	8.1
167	86 09 29	18 24 38	18 37 21	LG	35R	60	28	53	239	9	11.4
168	86 10 03	19 57 03	20 38 12	LG	25L	80	21U	32	1672	9	8.0
169	86 10 08	20 30 39	20 35 02	LG	20L	70	66	68	197	7	7.3
170	86 10 12	18 32 57	19 01 34	LG	30R	70	64U	20	1309	9	8.0
171	86 10 13	17 00 48	17 28 41	LG	45R	40	28U	28	325	7	9.0
172	86 10 14	03 23 10	03 34 24	LG	90L	50	46	43	135	7	10.4
173	86 10 15	17 51 07	18 20 02	LG	35R	60	41U	33	1274	9	8.1
174	86 10 16	04 15 41	04 24 23	LG	120L	65	63	47	71	5	9.7
175	86 10 16	20 01 04	20 30 29	LG	20L	70	44U	33	1309	9	8.8
176	86 10 17	02 56 42	03 02 28	LG	90L	45	42	37	54	5	8.6
177	86 10 19	19 20 09	20 03 17	LG	25L	80	28U	20	1904	9	9.0
178	86 10 22	18 54 50	19 16 19	LG	25L	85	52U	56	756	7	9.2
179	86 10 23	05 09 10	05 36 32	LG	-210R	85	69U	26	227	5	10.0
180	86 10 30	18 25 34	19 05 12	LG	25L	85	27U	31	1320	9	8.2

Table 4. Observations and data evaluation

(8) No.	(9) STN	(10) TMP	(11) PRESS	(12) HUM	(13) IDT	(14) DTS	(15) DTL	(16) COMMENTS
		°C	mb	%	ns	μs	μs	
121	7838	13.5	1010.1	93	8.0	-0.3	-1.4	
122	7838	17.4	1012.3	72	7.9	-0.5	-1.4	
123	7838	14.4	1013.2	86	7.9	-0.8	-1.4	
124	7838	17.5	1012.3	79	7.9	-0.6	-1.3	
125	7838	12.4	1014.3	90	7.9	-0.3	-1.2	
126	7838	15.0	997.3	88	7.8	-0.4	-1.0	
127	7838	18.0	1003.8	60	7.8	-0.6	-0.9	
128	7838	16.2	1005.6	80	7.7	-0.5	-0.9	
129	7838	20.1	1001.0	73	7.9	-0.5	-0.8	
130	7838	17.3	1001.4	91	7.8	-0.6	-0.8	
131	7838	18.4	1008.4	83	7.8	-0.4	-0.5	
132	7838	18.2	1009.9	87	7.9	-0.6	-0.5	
133	7838	15.6	994.0	56	7.7	-0.4	-0.3	
134	7838	16.0	1002.0	50	7.6	-0.7	-0.3	
135	7838	18.8	1008.0	60	7.7	-0.2	-0.2	
136	7838	14.8	1010.6	77	7.8	-0.3	-0.2	
137	7838	13.5	1008.8	75	7.0	-0.5	-0.2	
138	7838	19.4	1001.6	80	7.2	-0.4	-0.3	
139	7838	18.1	1003.6	89	5.9	-0.3	-0.2	
140	7838	21.7	1002.9	65	5.7	-0.6	-0.2	
141	7838	19.5	1011.4	59	6.5	-0.6	-0.2	
142	7838	23.3	1001.2	60	6.5	-0.4	-0.4	
143	7838	25.2	995.7	60	6.7	-0.4	-0.4	
144	7838	27.5	1009.9	84	9.2	-0.4	-1.8	DAYTIME
145	7838	26.6	1009.6	90	7.0	-0.4	-1.8	
146	7838	27.1	1009.7	81	6.6	-0.5	-1.8	DAYTIME
147	7838	29.6	987.2	47	6.5	-0.6	-1.9	DAYTIME
148	7838	27.1	990.4	52	6.6	-0.6	-1.9	
149	7838	28.1	994.9	55	6.6	-0.6	-1.9	DAYTIME
150	7838	25.7	1008.0	84	6.9	-0.5	-2.2	DAYTIME
151	7838	26.1	1006.4	91	7.4	-0.3	-2.3	
152	7838	28.8	1008.5	82	7.1	-0.6	-2.3	DAYTIME
153	7838	22.5	1001.2	95	7.1	-0.4	-2.4	
154	7838	25.7	997.7	92	7.1	-0.3	-2.5	DAYTIME
155	7838	25.1	999.9	96	7.2	-0.2	-2.6	DAYTIME
156	7838	18.9	1006.4	96	7.0	-0.3	-2.5	
157	7838	24.6	1003.2	81	5.9	-0.8	-2.4	
158	7838	22.3	1009.3	87	7.1	-0.6	-2.3	
159	7838	27.8	1002.1	67	7.1	-0.5	-2.1	DAYTIME
160	7838	24.9	1003.2	84	6.9	-0.6	-1.9	
161	7838	26.0	1005.1	67	6.9	-0.4	-1.8	DAYTIME
162	7838	17.6	1008.7	78	7.1	-0.3	-1.7	
163	7838	18.5	1009.5	77	7.2	-0.4	-1.7	DAYTIME
164	7838	26.2	1008.4	57	7.1	-0.5	-1.7	DAYTIME
165	7838	14.7	1010.8	75	7.0	-0.4	-1.7	
166	7838	19.5	1001.9	76	7.1	-0.3	-1.5	
167	7838	18.2	1003.4	85	6.9	-0.4	-1.5	
168	7838	16.2	1011.6	67	7.2	-0.6	-1.3	
169	7838	14.8	1009.4	67	7.1	-0.7	-1.0	
170	7838	14.9	1006.6	81	7.1	-0.2	-0.7	
171	7838	14.3	1010.2	77	7.1	-0.3	-0.6	
172	7838	23.0	1009.9	59	7.4	-0.4	-0.5	DAYTIME
173	7838	14.9	1009.2	85	7.2	-0.6	-0.4	
174	7838	25.2	1007.5	45	7.0	-0.3	-0.3	DAYTIME
175	7838	12.9	1009.7	76	7.3	-0.6	-0.3	
176	7838	21.7	1009.7	42	7.3	-0.4	-0.2	DAYTIME
177	7838	11.2	1020.2	61	7.1	-0.6	-0.1	
178	7838	8.9	1013.6	71	7.1	-0.1	0.0	
179	7838	18.2	1015.7	55	7.3	-0.5	0.1	DAYTIME
180	7838	7.5	1019.9	68	7.3	-0.9	0.3	

Table 4. Observations and data evaluation

(1) No.	(2) Obs.Time(UTC) date	caught	lost	(3) SAT.	(4)Az. ST	(5)Elev. MX	CT	LT	(6) RTN	(7)Fitting N	RMS
	Y M D	h m s	h m s		°	°	°	°			cm
181	86 10 31	04 49 10	05 08 54	LG	-210R	85	69U	46	63	5	9.6
182	86 10 31	17 06 48	17 29 38	LG	35R	60	32U	55	551	9	10.0
183	86 11 06	03 38 03	04 08 43	LG	130L	70	54U	25	1114	9	8.4
184	86 11 09	18 54 11	19 36 31	LG	20L	70	27U	20	1070	9	8.9
185	86 11 10	01 54 59	02 00 14	LG	90L	45	42	40	38	5	9.9
186	86 11 11	19 42 48	20 12 13	LG	20L	50	26U	38	651	9	8.7
187	86 11 12	02 44 53	02 55 32	LG	110L	55	53	34	102	3	10.9
188	86 11 17	18 33 05	19 10 04	LG	20L	65	24U	34	1482	9	10.7
189	86 11 18	17 09 18	17 50 45	LG	30R	80	22U	32	404	9	13.3
190	86 11 19	15 49 58	16 30 39	LG	40R	50	24U	21	643	9	7.6
191	86 11 21	16 41 59	17 16 35	LG	30R	70	37U	31	828	9	9.4
192	86 11 25	15 03 20	15 16 53	LG	50R	33	32	20	70	5	11.7
193	86 11 26	04 42 21	05 00 28	LG	-190R	65	65U	34	334	5	8.7
194	86 11 26	16 51 16	17 13 55	LG	30R	85	26	81	101	5	12.4
195	86 11 27	15 30 01	16 10 58	LG	40R	50	24U	20	616	9	10.0
196	86 11 28	02 03 02	02 11 08	LG	110L	55	55	42	56	5	8.5
197	86 11 30	15 02 35	15 28 52	LG	45R	40	31U	29	237	7	10.5
198	86 12 01	17 10 18	17 49 23	LG	25L	85	39U	22	1135	9	9.4
199	86 12 02	15 42 03	16 25 29	LG	35R	60	22U	23	1078	9	9.2
200	86 12 04	16 32 57	17 07 51	LG	30R	80	30U	40	189	9	11.2
201	86 12 05	15 09 17	15 44 10	LG	40R	50	23U	33	315	7	11.0
202	86 12 07	15 56 45	16 41 10	LG	30R	70	25U	21	1176	9	9.9
203	86 12 08	02 30 53	02 36 20	LG	130L	75	70	57	50	7	8.9
204	86 12 08	14 37 30	15 14 08	LG	45R	40	24U	21	368	9	11.8
205	86 12 08	18 08 21	18 48 44	LG	20L	60	26U	21	591	9	9.3
206	86 12 09	16 42 57	17 30 03	LG	25L	85	21U	20	590	7	9.5
207	86 12 10	15 27 47	16 03 41	LG	35R	60	34U	26	724	9	10.0
208	86 12 10	18 55 46	19 21 43	LG	20L	45	22U	39	159	9	9.1
209	86 12 11	14 09 59	14 36 21	LG	50R	33	27U	21	73	5	10.1
210	86 12 11	17 33 22	18 16 15	LG	20L	65	25U	21	836	9	10.3
211	86 12 12	16 10 08	16 55 44	LG	30R	85	24U	21	1675	9	10.0
212	86 12 12	19 46 57	20 12 22	LG	20L	35	25U	24	143	7	11.4
213	86 12 15	15 36 30	16 21 26	LG	30R	70	24U	21	1286	9	11.0
214	86 12 15	19 10 41	19 41 27	LG	20L	40	23U	24	632	7	10.9
215	86 12 20	00 08 43	00 24 40	LG	80L	45	40U	35	193	9	10.2
216	86 12 22	00 48 32	01 14 23	LG	110L	55	39U	37	219	7	9.7
217	86 12 22	16 37 47	17 23 29	LG	25L	75	22U	20	924	9	11.7
218	86 12 23	15 15 09	16 01 49	LG	30R	70	21U	20	1607	9	10.9
219	86 12 23	18 50 49	19 22 45	LG	20L	40	23U	22	482	7	11.5
220	86 12 24	01 38 20	02 00 20	LG	130L	75	55U	46	266	7	11.7
221	86 12 24	13 55 50	14 34 37	LG	45R	40	21U	20	527	7	11.9
222	86 12 24	17 26 08	18 08 26	LG	20L	60	21U	21	950	9	10.5
223	86 12 25	16 04 24	16 49 46	LG	25R	85	24U	21	1290	9	13.5
224	86 12 26	14 45 09	15 18 00	LG	35R	60	29U	39	710	9	10.9

Table 4. Observations and data evaluation

(8) No.	(9) STN	(10) TMP	(11) PRESS	(12) HUM	(13) IDT	(14) DTS	(15) DTL	(16) COMMENTS
		°C	mb	%	ns	μs	μs	
181	7838	16.2	1019.9	50	7.2	-0.9	0.3	DAYTIME
182	7838	10.8	1018.0	86	6.9	0.0	0.3	
183	7838	18.1	1017.1	40	7.2	-0.5	0.5	DAYTIME
184	7838	11.7	1004.2	68	7.3	-0.5	0.5	
185	7838	17.0	1007.5	50	7.2	-0.5	0.5	DAYTIME
186	7838	7.2	1019.1	65	7.2	-0.4	0.6	
187	7838	16.4	1019.7	59	7.3	-0.4	0.6	DAYTIME
188	7838	8.7	1014.3	70	6.4	-0.6	0.7	
189	7838	10.6	1012.5	69	7.1	-0.6	0.8	
190	7838	9.4	1013.4	71	7.2	-0.6	0.8	
191	7838	8.5	1020.8	80	7.3	-0.3	0.8	
192	7838	15.0	1008.0	51	7.1	-0.4	0.9	
193	7838	13.6	1014.6	45	7.1	-0.5	0.9	DAYTIME
194	7838	5.3	1022.6	65	7.1	-0.5	0.9	
195	7838	6.0	1024.0	77	7.2	-0.1	0.9	
196	7838	15.0	1023.0	68	7.3	-0.4	0.9	DAYTIME
197	7838	6.3	1018.6	72	7.4	-0.5	1.0	
198	7838	9.3	1019.7	60	7.1	-0.1	1.0	
199	7838	8.8	1017.4	87	7.2	-0.4	1.0	
200	7838	8.0	1008.0	61	7.2	-0.2	1.0	
201	7838	6.4	1016.2	74	7.3	-0.5	1.0	
202	7838	6.5	1014.9	58	7.7	-0.3	0.9	
203	7838	12.8	1016.9	48	7.9	-0.3	0.9	DAYTIME
204	7838	7.0	1018.1	70	7.8	0.2	0.9	
205	7838	6.9	1017.5	70	8.1	-0.3	0.9	
206	7838	8.2	1016.3	89	7.8	-0.5	0.9	
207	7838	8.2	1011.9	77	8.0	-0.4	0.8	
208	7838	6.6	1012.5	79	7.9	-0.6	0.8	
209	7838	8.5	1016.3	69	7.7	-0.4	0.8	
210	7838	7.6	1015.7	64	7.8	-0.8	0.8	
211	7838	9.8	1019.3	55	7.5	-0.6	0.8	
212	7838	9.0	1019.6	59	7.6	0.0	0.8	
213	7838	6.9	1014.3	81	7.4	-0.6	0.8	
214	7838	4.6	1015.6	90	7.5	-0.5	0.8	
215	7838	8.7	1012.7	54	7.4	-0.4	0.6	DAYTIME
216	7838	10.8	1015.7	49	7.4	-0.4	0.6	DAYTIME
217	7838	3.8	1021.1	62	7.6	-0.2	0.6	
218	7838	8.7	1015.2	81	7.6	-0.4	0.6	
219	7838	9.8	1014.4	65	7.6	-0.4	0.6	
220	7838	15.5	1014.3	52	7.5	-0.5	0.5	DAYTIME
221	7838	6.9	1013.7	79	7.4	-0.3	0.5	
222	7838	7.8	1012.1	81	7.4	-0.5	0.5	
223	7838	9.0	1012.7	72	7.6	-0.4	0.5	
224	7838	4.2	1019.5	73	7.5	-0.2	0.5	

Table 4. Observations and data evaluation

(1) No.	(2) Obs.Time(UTC) date	caught	lost	(3) SAT.	(4)Az. ST	(5)Elev. MX	CT	LT	(6) RTN	(7)Fitting N	RMS
	Y M D	h m s	h m s		°	°	°	°			cm
1	86 01 05	23 35 23	23 42 28	ST	-60L	60	23U	32	393	10	7.8
2	86 01 06	14 44 21	14 51 03	ST	200L	55	32U	29	288	11	10.3
3	86 01 08	15 22 39	15 31 00	ST	-110R	60	29U	24	215	11	10.8
4	86 01 13	13 23 20	13 30 39	ST	-125R	80	51U	20	265	13	9.9
5	86 01 14	11 52 09	12 00 05	ST	190L	40	24U	21	30	13	11.6
6	86 01 17	18 22 53	18 31 55	ST	-35R	50	23U	21	263	17	9.1
7	86 01 20	10 10 25	10 17 06	ST	200L	50	25U	32	478	12	8.6
8	86 01 23	09 19 44	09 27 57	ST	205L	55	26U	21	388	18	9.3
9	86 01 27	08 48 00	08 55 22	ST	-125R	80	24U	32	536	18	9.0
10	86 01 28	09 12 25	09 15 42	ST	-105R	45	45U	24	68	9	10.2
11	86 01 31	06 29 49	06 35 13	ST	190L	45	33U	24	141	10	11.3
12	86 02 03	05 39 15	05 43 16	ST	200L	50	36U	35	114	10	8.8
13	86 02 04	06 00 45	06 04 52	ST	225L	85	81U	22	185	9	10.0
14	86 02 05	13 38 07	13 42 50	ST	-60L	60	27U	58	131	8	11.8
15	86 02 07	12 28 13	12 33 14	ST	-50L	85	31U	64	98	7	9.9
16	86 02 08	12 47 47	12 56 18	ST	-65L	55	29U	20	1024	12	12.8
17	86 02 11	11 57 56	12 02 26	ST	-65L	50	34U	40	47	6	11.1
18	86 02 12	03 06 04	03 13 20	ST	215L	65	28U	20	157	10	8.9
19	86 02 17	08 27 34	08 34 23	ST	-35R	55	38U	21	51	10	11.3
20	86 02 20	00 16 07	00 21 24	ST	200L	50	37U	22	123	16	9.8
21	86 02 22	00 53 32	00 59 18	ST	-105R	50	23U	30	328	18	9.5
22	86 02 23	23 43 51	23 46 09	ST	-125R	75	30	71	61	15	9.5
23	86 02 24	07 04 31	07 12 23	ST	-50L	80	30U	23	397	18	8.9
24	86 02 25	00 05 39	00 07 23	ST	-95R	45	44U	40	74	15	10.3
25	86 02 25	05 34 31	05 42 07	ST	-30R	45	22U	21	226	17	9.5
26	86 02 26	05 54 47	06 02 06	ST	-40R	70	33U	22	240	17	11.3
27	86 03 04	04 13 15	04 20 54	ST	-45R	80	30U	20	436	18	15.5
28	86 03 12	01 25 00	01 27 37	ST	-40R	70	66	33	172	16	9.1
29	86 03 13	01 43 14	01 45 19	ST	-55L	65	55U	61	175	8	8.8
30	86 03 31	11 47 44	11 53 29	ST	225L	85	43U	30	247	17	9.6
31	86 04 01	12 05 11	12 13 32	ST	-110R	60	22U	24	178	17	11.3
32	86 04 23	12 03 10	12 10 13	ST	-55L	75	28U	28	289	13	8.4
33	86 04 24	05 04 46	05 06 58	ST	-100R	50	49	33	26	5	7.8
34	86 05 07	00 11 05	00 12 21	ST	-125R	80	76	59	24	5	10.9
35	86 05 07	07 34 00	07 37 00	ST	-55L	75	74	33	57	9	11.1
36	86 05 09	06 21 49	06 25 50	ST	-45R	75	56U	44	71	7	9.4
37	86 05 15	04 39 29	04 45 23	ST	-50R	85	47U	33	34	14	10.9
38	86 05 23	01 46 30	10 49 05	ST	-45R	75	34U	68	45	8	13.5
39	86 06 08	13 01 43	13 08 19	ST	220L	75	32U	21	258	17	12.3
40	86 06 11	12 11 47	12 16 41	ST	225L	80	42U	30	168	16	13.9
41	86 06 12	12 30 16	12 36 47	ST	-105R	50	25U	22	236	17	13.5
42	86 06 19	09 19 57	09 24 28	ST	215L	65	32U	41	184	17	12.8
43	86 07 29	04 17 13	04 18 17	ST	-55L	75	56	38	31	5	6.6
44	86 07 30	02 45 45	02 48 45	ST	-30R	45	42	29	82	9	9.4
45	86 07 30	04 35 33	04 36 24	ST	-75L	45	41	37	66	7	8.8
46	86 07 31	03 02 31	03 10 02	ST	-40R	70	27U	20	455	16	7.9
47	86 08 01	03 23 36	03 28 47	ST	-55L	65	45U	25	43	8	6.5
48	86 08 05	01 01 45	01 04 33	ST	-35R	55	27	52	57	9	8.9
49	86 08 07	01 40 41	01 47 42	ST	-65L	55	27U	23	451	12	9.5
50	86 08 09	00 30 29	00 34 31	ST	-50L	85	30	75	289	9	8.4
51	86 08 12	14 49 48	14 55 30	ST	190L	45	39U	21	118	8	9.1
52	86 08 20	13 45 34	13 49 36	ST	-105R	60	37	55	118	8	7.0
53	86 08 30	17 04 39	17 14 06	ST	-45R	80	27U	20	1089	20	11.9
54	86 09 03	09 11 23	09 15 05	ST	-110R	60	26	60	83	11	10.8
55	86 09 03	14 43 53	14 52 38	ST	-35R	40	22U	20	445	10	8.9
56	86 09 04	07 42 21	07 48 47	ST	200L	55	28U	28	566	11	8.7
57	86 09 22	02 38 11	02 45 38	ST	-125R	75	26U	20	411	12	8.3
58	86 09 22	09 58 50	10 04 06	ST	-50L	80	24U	67	499	10	10.6
59	86 09 24	08 48 25	08 56 56	ST	-40R	70	22U	26	463	18	9.8
60	86 09 25	09 08 34	09 16 27	ST	-55L	70	27U	26	358	16	8.6

Table 4. Observations and data evaluation

(8) No.	(9) STN	(10) TMP	(11) PRESS	(12) HUM	(13) IDT	(14) DTS	(15) DTL	(16) COMMENTS
		°C	mb	%	ns	μs	μs	
1	7838	1.7	1006.2	71	7.4	-1.2	-0.7	DAYTIME
2	7838	-0.6	1010.8	67	7.5	-0.6	-0.7	
3	7838	1.9	1010.1	84	7.4	-0.5	-0.7	
4	7838	4.4	1007.3	49	7.5	-0.4	-0.8	
5	7838	3.5	1011.1	55	7.2	-0.4	-0.8	
6	7838	2.3	1010.6	74	7.5	-0.4	-0.9	
7	7838	8.5	1007.5	83	7.0	-0.2	-0.9	
8	7838	3.8	1004.7	59	7.3	-0.1	-1.0	
9	7838	2.5	1011.0	61	7.3	-0.5	-0.9	
10	7838	4.4	1011.9	86	7.2	-0.7	-0.9	
11	7838	12.0	1003.8	40	7.3	-0.4	-0.8	DAYTIME
12	7838	13.3	1002.7	25	7.1	-0.6	-0.7	DAYTIME
13	7838	7.3	1007.3	36	7.3	-0.3	-0.7	DAYTIME
14	7838	1.7	1011.4	45	7.1	-0.4	-0.7	
15	7838	2.3	1009.3	58	7.0	-0.6	-0.7	O FITTING
16	7838	-0.3	1012.4	70	7.3	-1.0	-0.8	
17	7838	2.3	1004.9	60	6.9	-1.2	-0.7	
18	7838	10.3	1010.7	24	7.4	-0.5	-0.7	DAYTIME
19	7838	6.9	1015.8	53	7.2	-0.6	-0.5	DAYTIME
20	7838	7.5	1010.1	40	7.1	-0.8	-0.4	DAYTIME
21	7838	9.2	1007.4	42	7.7	-0.2	-0.3	DAYTIME
22	7838	5.0	1005.3	43	7.4	-0.4	-0.2	DAYTIME
23	7838	6.8	1003.3	20	7.5	-0.5	-0.2	DAYTIME
24	7838	3.5	1011.9	62	7.6	-0.3	-0.2	DAYTIME
25	7838	7.8	1008.4	24	7.6	-0.4	-0.2	DAYTIME
26	7838	9.9	1008.6	39	7.6	-0.5	-0.2	DAYTIME
27	7838	10.0	1010.5	51	7.6	-0.5	-0.5	DAYTIME
28	7838	12.1	1009.5	34	7.5	-0.3	-1.3	DAYTIME
29	7838	14.7	1016.0	39	7.5	-0.5	-1.3	DAYTIME
30	7838	9.3	1008.6	38	7.5	-0.2	-1.7	
31	7838	6.8	1011.6	71	7.6	-0.5	-1.8	
32	7838	15.3	1009.0	89	8.0	-0.4	-1.4	
33	7838	20.7	1011.7	56	8.0	-0.6	-1.4	DAYTIME
34	7838	19.0	1002.2	56	7.9	-0.4	-0.9	DAYTIME
35	7838	22.5	1001.6	55	8.0	-0.6	-0.9	DAYTIME
36	7838	23.0	998.6	65	8.0	-0.6	-0.8	DAYTIME
37	7838	21.2	989.4	42	7.8	-0.3	-0.3	DAYTIME
38	7838	18.9	1008.4	50	7.0	-0.4	-0.2	DAYTIME
39	7838	17.8	1003.8	89	5.3	-0.4	-0.2	
40	7838	19.2	1011.7	58	6.6	-0.6	-0.2	
41	7838	18.5	1015.6	75	6.7	-0.5	-0.2	
42	7838	25.5	1000.1	53	7.0	-0.4	-0.4	DAYTIME
43	7838	28.3	1008.8	84	9.4	-0.3	-1.7	DAYTIME
44	7838	28.1	1009.8	84	9.4	-0.1	-1.7	DAYTIME
45	7838	28.2	1009.3	84	9.3	-0.4	-1.7	DAYTIME
46	7838	28.1	1009.9	84	9.4	-0.3	-1.8	DAYTIME
47	7838	28.9	1009.3	83	6.6	-0.4	-1.8	DAYTIME
48	7838	30.0	987.2	46	6.4	-0.5	-1.9	DAYTIME
49	7838	27.2	1000.5	74	6.4	-0.4	-2.1	DAYTIME
50	7838	27.2	1008.6	81	7.1	-0.2	-2.3	DAYTIME
51	7838	24.2	1005.3	97	7.2	-0.3	-2.3	
52	7838	25.5	994.9	93	6.9	-0.6	-2.5	
53	7838	21.8	1002.7	82	7.1	-0.2	-2.5	
54	7838	30.5	998.8	51	7.2	-0.7	-2.4	DAYTIME
55	7838	24.1	1002.0	78	6.0	-0.5	-2.4	
56	7838	29.1	1004.5	73	5.8	-0.7	-2.3	DAYTIME
57	7838	26.3	1005.6	67	7.2	-0.5	-1.8	DAYTIME
58	7838	22.5	1007.7	88	7.1	-0.4	-1.8	
59	7838	22.5	1007.7	69	7.0	-0.5	-1.7	DAYTIME
60	7838	22.7	1008.9	72	7.0	-0.3	-1.7	

Table 4. Observations and data evaluation

(1) No.	(2) Obs.Time(UTC) date	caught	lost	(3) SAT.	(4)Az. ST	(5)Elev. MX	CT	LT	(6) RTN	(7)Fitting N	RMS
	Y M D	h m s	h m s		°	°	°	°		'	cm
61	86 09 26	07 38 48	07 46 15	ST	-35R	45	24U	25	551	14	8.7
62	86 09 26	09 27 59	09 36 05	ST	-70L	45	23U	20	391	16	8.8
63	86 09 28	23 28 43	23 34 16	ST	195L	45	30U	21	163	16	9.9
64	86 09 29	06 48 26	06 56 01	ST	-30R	50	26U	22	560	18	9.8
65	86 09 29	23 50 21	23 53 29	ST	225L	85	82	26	213	11	11.5
66	86 10 08	21 20 38	21 22 13	ST	-120R	37	37	21	88	7	7.7
67	86 10 13	02 16 07	02 23 00	ST	-35R	50	26U	20	466	18	10.8
68	86 10 16	01 26 30	01 31 32	ST	-25R	50	37U	26	600	19	11.6
69	86 10 23	00 03 19	00 09 15	ST	-60L	70	24U	34	461	18	9.5
70	86 11 04	11 50 42	11 57 32	ST	210L	65	36U	25	865	19	11.6
71	86 11 05	12 08 21	12 17 38	ST	-120R	75	21U	20	761	17	9.0
72	86 11 12	08 57 12	09 06 08	ST	190L	55	21U	23	831	11	8.9
73	86 11 18	07 16 11	07 23 30	ST	210L	70	28U	34	272	11	9.4
74	86 11 19	07 36 29	07 43 37	ST	-120R	75	35U	29	221	17	10.0
75	86 11 19	14 57 46	15 05 54	ST	-55L	70	23U	20	732	19	12.5
76	86 11 21	06 27 13	06 34 20	ST	220L	75	48U	22	194	11	7.3
77	86 11 25	05 57 14	06 01 46	ST	-115R	65	59U	31	302	9	8.4
78	86 11 25	13 22 43	13 24 34	ST	-60L	60	36	20	93	7	8.3
79	86 11 26	06 15 33	06 21 15	ST	-95R	45	34U	27	207	17	9.5
80	86 11 27	04 45 21	04 52 41	ST	-130R	85	46U	23	296	17	9.9
81	86 11 28	05 05 00	05 11 14	ST	-105R	60	41U	27	335	18	9.1
82	86 12 01	02 28 10	02 29 55	ST	170L	40	39	31	69	7	8.0
83	86 12 01	04 18 01	04 19 34	ST	-105R	50	48	35	36	8	9.9
84	86 12 02	02 47 48	02 49 09	ST	210L	70	60	44	67	15	9.7
85	86 12 05	09 16 11	09 23 09	ST	-45R	75	43U	22	147	10	11.7
86	86 12 08	01 05 59	01 09 30	ST	220L	80	70	26	103	8	9.6
87	86 12 08	08 24 00	08 31 03	ST	-45R	80	30U	34	171	10	10.0
88	86 12 09	08 42 47	08 50 52	ST	-60L	60	23U	28	234	11	9.5
89	86 12 11	07 33 24	07 41 07	ST	-50R	85	31U	27	276	17	9.8
90	86 12 12	07 55 01	07 59 04	ST	-65L	55	48U	37	226	17	9.4
91	86 12 24	02 40 19	02 49 06	ST	-40R	60	29U	20	662	19	12.1
92	86 12 26	01 29 36	01 38 00	ST	-25R	40	24U	21	148	16	13.2

Table 4. Observations and data evaluation

(8) No.	(9) STN	(10) TMP	(11) PRESS	(12) HUM	(13) IDT	(14) DTS	(15) DTL	(16) COMMENTS
		°C	mb	%	ns	µs	µs	
61	7838	23.2	1011.2	72	7.1	-0.4	-1.6	DAYTIME
62	7838	22.3	1011.9	76	7.1	-0.5	-1.6	
63	7838	24.0	1001.8	63	6.9	-0.3	-1.5	DAYTIME
64	7838	27.3	998.4	64	7.1	-0.4	-1.6	DAYTIME
65	7838	23.9	1007.1	70	6.8	-0.5	-1.5	DAYTIME
66	7838	14.9	1009.9	66	7.2	-0.6	-1.0	DAYTIME
67	7838	23.1	1007.8	62	7.2	-0.2	-0.6	DAYTIME
68	7838	23.6	1010.1	50	7.1	-0.3	-0.3	DAYTIME
69	7838	14.7	1017.5	51	7.4	-0.5	0.1	DAYTIME
70	7838	14.0	1009.3	75	7.2	-0.6	0.4	
71	7838	11.1	1014.9	68	7.2	-0.6	0.4	
72	7838	11.6	1019.7	79	7.3	-0.3	0.6	
73	7838	16.3	1013.6	64	7.0	-0.6	0.8	DAYTIME
74	7838	15.1	1011.4	58	7.1	-0.5	0.8	DAYTIME
75	7838	9.8	1013.4	70	7.3	-0.4	0.8	
76	7838	16.4	1019.5	60	7.2	-0.5	0.8	DAYTIME
77	7838	22.6	1004.9	59	7.0	-0.6	0.9	DAYTIME
78	7838	16.3	1007.8	64	7.1	-0.3	0.9	
79	7838	13.0	1015.8	46	7.0	-0.5	0.9	DAYTIME
80	7838	12.4	1023.4	53	7.2	-0.3	0.9	DAYTIME
81	7838	16.6	1019.7	56	7.2	-0.3	0.9	DAYTIME
82	7838	15.2	1019.0	49	7.1	-0.4	1.0	DAYTIME
83	7838	14.8	1017.2	53	7.0	-0.2	1.0	DAYTIME
84	7838	15.0	1020.0	63	7.2	-0.3	1.0	DAYTIME
85	7838	8.8	1014.2	77	7.1	-0.2	1.0	
86	7838	11.1	1017.6	51	7.8	-0.2	0.9	DAYTIME
87	7838	9.2	1017.7	65	7.9	-0.4	0.9	
88	7838	11.8	1016.5	78	7.9	-0.1	0.9	
89	7838	13.6	1014.7	66	8.0	-0.5	0.8	DAYTIME
90	7838	15.3	1016.7	62	7.5	-0.6	0.8	
91	7838	16.1	1013.1	47	7.3	-0.3	0.5	DAYTIME
92	7838	12.0	1018.3	50	7.5	-0.3	0.5	DAYTIME

Table 4. Observations and data evaluation

(1) No.	(2) Obs.Time(UTC) date	caught	lost	(3) SAT.	(4)Az. ST	(5)Elev. MX	CT	LT	(6) RTN	(7)Fitting N	RMS
	Y M D	h m s	h m s		°	°	°	°			cm
1	86 01 04	20 32 38	20 38 40	BC	-95R	65	50U	34	103	8	8.9
2	86 01 05	19 50 41	19 55 16	BC	-105R	75	55U	47	325	10	9.0
3	86 01 06	01 33 05	01 38 53	BC	-70L	60	29U	50	620	11	7.8
4	86 01 09	17 00 07	17 10 00	BC	220L	60	25U	21	763	19	10.4
5	86 01 10	16 18 21	16 27 11	BC	205L	50	23U	24	475	14	10.2
6	86 01 11	00 02 10	00 06 05	BC	-75L	55	53	26	209	9	6.5
7	86 01 11	17 29 54	17 38 43	BC	-110R	80	25U	33	465	18	9.4
8	86 01 13	16 06 17	16 09 34	BC	235L	75	26	64	175	8	11.2
9	86 01 14	15 26 08	15 30 26	BC	220L	60	39U	51	108	16	9.9
10	86 01 16	15 54 33	16 03 28	BC	-105R	75	26U	27	485	18	10.4
11	86 01 23	18 38 33	18 48 43	BC	-65L	80	25U	24	781	19	9.2
12	86 01 25	13 25 58	13 34 46	BC	-90R	60	24U	20	692	19	10.1
13	86 01 28	13 14 43	13 22 51	BC	-75R	45	23U	21	222	17	10.1
14	86 01 29	12 33 29	12 40 34	BC	-80R	50	28U	23	72	11	8.9
15	86 01 31	13 03 35	13 11 32	BC	-60R	45	23U	20	271	17	11.5
16	86 02 02	13 35 49	13 42 12	BC	-55R	50	38U	22	154	12	11.4
17	86 02 03	12 56 59	13 00 24	BC	-55R	45	44	20	149	12	9.1
18	86 02 05	13 25 17	13 30 54	BC	-60R	65	58U	23	283	17	10.2
19	86 02 06	06 58 21	07 05 28	BC	200L	40	22U	22	302	17	10.0
20	86 02 07	13 55 45	13 58 07	BC	-70L	65	58U	50	98	7	11.2
21	86 02 10	06 07 43	06 12 25	BC	220L	60	57U	22	180	11	10.1
22	86 02 11	11 05 43	11 12 42	BC	-55R	65	26U	28	344	12	12.1
23	86 02 12	06 34 34	06 42 29	BC	-105R	70	27U	24	352	18	11.1
24	86 02 22	03 24 19	03 30 32	BC	-100R	70	37U	36	124	16	9.5
25	86 02 24	02 00 20	02 08 56	BC	240L	85	41U	20	441	18	11.3
26	86 02 24	05 48 41	05 55 21	BC	-60R	50	23U	35	81	13	7.4
27	86 02 25	07 01 24	07 08 22	BC	-65R	85	28U	33	527	18	13.4
28	86 02 26	04 29 46	04 32 37	BC	-60R	45	44	24	95	7	10.5
29	86 02 26	06 18 54	06 26 35	BC	-60R	70	24U	32	474	18	11.3
30	86 02 28	01 07 11	01 15 16	BC	-105R	75	48U	20	455	16	8.8
31	86 03 03	04 45 49	04 52 38	BC	-60R	80	51U	22	276	17	10.9
32	86 03 05	01 31 01	01 33 23	BC	-70R	50	39	23	37	6	8.2
33	86 03 05	03 21 41	03 26 56	BC	-60R	65	46U	36	187	13	9.3
34	86 03 06	00 41 32	00 49 18	BC	-75R	50	23U	37	45	14	12.6
35	86 03 07	01 55 57	02 00 03	BC	-60R	55	32	53	43	8	6.7
36	86 03 08	03 12 56	03 13 24	BC	-65R	85	75	66	45	10	10.7
37	86 03 12	23 40 22	23 44 35	BC	-60R	50	49	36	179	9	9.0
38	86 03 13	01 34 21	01 36 46	BC	-65L	85	56U	82	61	9	9.9
39	86 03 17	00 37 11	00 42 54	BC	-65L	75	25	71	368	12	10.2
40	86 03 20	00 26 01	00 33 55	BC	-80L	45	26U	30	213	17	9.2
41	86 03 23	15 55 46	16 00 28	BC	230L	70	53U	42	358	10	12.4
42	86 04 10	10 57 29	11 01 59	BC	-95R	60	44U	36	190	11	10.1
43	86 04 12	11 31 51	11 34 07	BC	-70R	45	35	20	87	7	8.5
44	86 04 23	05 44 40	05 47 10	BC	240L	90	57	25	184	9	13.8
45	86 04 23	07 36 56	07 41 00	BC	-75R	45	44U	23	243	9	9.8
46	86 04 24	06 55 19	06 58 23	BC	-80R	50	49U	29	127	8	8.5
47	86 04 24	10 40 44	10 47 22	BC	-65R	85	28U	32	798	19	10.5
48	86 05 09	02 09 03	02 11 10	BC	-80R	50	50	38	34	5	5.3
49	86 05 09	05 58 16	06 01 44	BC	-65L	75	75	29	300	13	10.3
50	86 05 15	01 44 58	01 49 28	BC	-60R	50	49	31	116	8	10.2
51	86 05 22	23 55 08	23 59 52	BC	-60R	65	39U	59	340	10	8.3
52	86 05 25	23 46 14	23 46 33	BC	-65L	90	81	87	33	6	9.9
53	86 06 08	13 52 29	13 59 46	BC	-105R	75	28U	34	115	16	10.5
54	86 06 09	13 13 59	13 17 36	BC	-115R	80	79	36	125	8	11.3
55	86 06 12	11 05 37	11 13 02	BC	210L	50	25U	22	717	15	10.8
56	86 06 19	09 59 58	10 06 51	BC	-110R	75	27U	31	313	17	12.2

Table 4. Observations and data evaluation

(8) No.	(9) STN	(10) TMP	(11) PRESS	(12) HUM	(13) IDT	(14) DTS	(15) DTL	(16) COMMENTS
		°C	mb	%	ns	µs	µs	
1	7838	1.5	997.9	61	7.4	-0.7	-0.7	
2	7838	-1.1	1004.2	88	7.4	-1.1	-0.7	
3	7838	3.8	1006.4	71	7.3	-1.0	-0.7	DAYTIME
4	7838	0.3	1015.6	60	7.5	-0.4	-0.7	
5	7838	-0.3	1014.8	57	7.7	-0.5	-0.7	
6	7838	3.1	1016.9	47	7.8	-0.2	-0.7	DAYTIME
7	7838	-1.3	1017.8	84	7.4	-0.5	-0.7	
8	7838	2.0	1008.2	59	7.6	-0.2	-0.8	
9	7838	0.8	1010.6	74	7.3	-0.7	-0.8	
10	7838	5.3	1005.8	70	7.2	-0.4	-0.9	
11	7838	2.7	1006.7	60	7.1	-0.5	-1.0	
12	7838	2.6	1010.1	74	7.0	-0.8	-0.9	
13	7838	1.2	1013.6	69	7.0	-1.1	-0.9	
14	7838	4.8	1013.8	58	7.1	-0.5	-0.9	
15	7838	5.2	1006.4	55	7.2	-0.4	-0.8	
16	7838	3.1	1009.5	62	7.0	-0.4	-0.8	
17	7838	4.6	1007.3	53	7.1	-0.5	-0.7	
18	7838	1.7	1011.4	45	7.3	-0.4	-0.7	
19	7838	9.5	1007.1	18	7.2	-0.6	-0.7	DAYTIME
20	7838	2.4	1008.8	52	7.2	-0.7	-0.7	O FITTING
21	7838	6.8	1013.1	41	7.4	-0.6	-0.7	DAYTIME
22	7838	3.1	1004.7	48	7.1	-1.5	-0.7	
23	7838	10.0	1010.4	32	7.4	-0.6	-0.7	DAYTIME
24	7838	11.3	1005.1	32	7.7	-0.4	-0.3	DAYTIME
25	7838	8.8	1005.0	33	7.7	-0.5	-0.2	DAYTIME
26	7838	8.3	1002.9	23	7.5	-0.6	-0.2	DAYTIME
27	7838	7.2	1009.2	26	7.5	-0.5	-0.2	DAYTIME
28	7838	8.5	1009.8	34	7.6	-0.6	-0.2	DAYTIME
29	7838	10.0	1008.4	37	7.5	-0.6	-0.2	DAYTIME
30	7838	4.8	1005.2	46	7.5	-0.4	-0.2	DAYTIME
31	7838	10.6	1004.0	34	7.5	-0.3	-0.4	DAYTIME
32	7838	13.2	1005.8	46	7.7	-0.6	-0.7	DAYTIME
33	7838	15.6	1004.6	32	7.6	-0.5	-0.7	DAYTIME
34	7838	11.2	1016.7	38	7.6	-0.2	-0.8	DAYTIME
35	7838	13.2	1018.6	63	7.7	-0.3	-1.0	DAYTIME
36	7838	16.2	1019.5	52	7.5	-0.5	-1.1	DAYTIME
37	7838	11.6	1016.7	44	7.5	-0.5	-1.3	DAYTIME
38	7838	14.1	1016.0	39	7.5	-0.5	-1.3	DAYTIME
39	7838	9.1	1008.8	30	7.6	-0.6	-1.5	DAYTIME
40	7838	10.2	1001.2	41	7.5	-0.3	-1.5	DAYTIME
41	7838	5.9	997.3	53	7.6	-0.6	-1.3	
42	7838	17.6	1002.5	97	7.6	-0.3	-1.7	
43	7838	10.2	1013.4	47	7.1	-0.5	-1.7	
44	7838	20.5	1005.3	70	7.9	-0.2	-1.4	DAYTIME
45	7838	20.3	1006.0	70	8.0	-0.4	-1.4	DAYTIME
46	7838	20.8	1011.0	68	8.0	-0.4	-1.4	DAYTIME
47	7838	17.1	1012.5	72	7.8	-0.6	-1.4	
48	7838	22.3	1001.2	70	7.8	-0.5	-0.8	DAYTIME
49	7838	23.7	998.8	65	8.0	-0.5	-0.8	DAYTIME
50	7838	22.9	990.1	48	7.8	-0.2	-0.3	DAYTIME
51	7838	18.5	1008.4	46	7.2	-0.4	-0.2	DAYTIME
52	7838	20.1	1004.7	39	7.3	-0.1	-0.3	DAYTIME
53	7838	16.5	1004.0	78	5.9	-0.4	-0.2	
54	7838	21.3	1004.2	67	5.8	-0.5	-0.2	
55	7838	19.1	1015.2	74	6.8	-0.7	-0.2	
56	7838	24.1	1000.9	60	7.1	-0.4	-0.4	DAYTIME

Table 4. Observations and data evaluation

(1) No.	(2) Obs.Time(UTC) date	caught	lost	(3) SAT.	(4)Az. ST	(5)Elev. MX	CT	LT	(6) RTN	(7)Fitting N	RMS
	Y M D	h m s	h m s		°	°	°	°			cm
1	86 08 13	17 43 13	17 53 44	AJ	-30R	35	22U	20	1581	11	7.0
2	86 08 13	19 46 43	19 50 52	AJ	-50R	90	36	86	186	7	17.0
3	86 08 14	10 40 39	10 46 29	AJ	175L	35	27U	34	624	11	7.5
4	86 08 14	12 43 29	12 47 51	AJ	-115R	65	54U	53	646	11	7.6
5	86 08 14	18 58 09	18 59 37	AJ	-40R	65	59	47	77	9	20.6
6	86 08 15	13 53 01	13 55 25	AJ	-75R	40	36	36	286	9	12.5
7	86 08 15	18 01 18	18 03 59	AJ	-35R	50	45U	45	105	10	23.1
8	86 08 16	10 52 30	11 04 10	AJ	210L	60	28U	20	1838	11	7.3
9	86 08 16	12 54 08	13 05 35	AJ	-90R	45	24U	22	1150	20	9.2
10	86 08 17	11 59 46	12 12 10	AJ	-110R	65	27U	20	1571	11	8.0
11	86 08 17	18 11 42	18 14 49	AJ	-40R	70	31	57	28	3	6.7
12	86 08 18	17 16 19	17 28 03	AJ	-30R	50	22U	23	1415	11	8.0
13	86 08 19	12 14 28	12 26 33	AJ	-85R	45	26U	20	1523	11	5.9
14	86 08 19	16 22 27	16 33 40	AJ	-25R	40	22U	20	1844	11	7.4
15	86 08 19	18 24 33	18 37 22	AJ	-55L	80	26U	20	2041	15	17.4
16	86 08 20	09 18 38	09 26 14	AJ	185L	45	25U	35	536	18	9.4
17	86 08 20	11 19 30	11 30 07	AJ	-105R	60	26U	29	859	15	9.0
18	86 08 20	15 28 24	15 38 14	AJ	-25R	32	21U	20	1391	11	6.6
19	86 08 20	17 29 48	17 43 10	AJ	-40R	70	22U	20	2383	14	12.2
20	86 08 24	15 59 19	16 00 47	AJ	-35R	55	46	55	205	9	13.7
21	86 08 26	16 09 44	16 17 09	AJ	-45R	80	26U	67	684	19	9.5
22	86 08 27	15 16 09	15 22 49	AJ	-35R	60	27U	56	624	13	9.0
23	86 08 28	10 16 00	10 23 09	AJ	-80R	40	33U	25	829	15	9.2
24	86 08 28	16 31 05	16 35 59	AJ	-55L	65	55	20	731	13	9.3
25	86 08 30	14 35 34	14 39 29	AJ	-40R	65	26	56	632	11	8.9
26	86 08 30	16 40 25	16 48 04	AJ	-70L	40	34U	21	734	11	8.6
27	86 08 31	13 42 37	13 47 03	AJ	-40R	50	30U	48	781	11	7.7
28	86 09 01	12 50 41	12 54 30	AJ	-35R	38	35U	34	221	9	8.8
29	86 09 03	06 51 06	07 02 22	AJ	-130R	85	37U	20	1620	11	7.9
30	86 09 03	08 54 41	09 03 47	AJ	-75R	35	27U	20	1165	11	6.6
31	86 09 03	15 02 33	15 15 01	AJ	-60L	55	22U	20	2044	11	6.9
32	86 09 04	05 59 29	06 08 10	AJ	205L	65	54U	20	917	11	7.7
33	86 09 04	08 04 15	08 09 51	AJ	-90R	45	44U	20	694	11	7.2
34	86 09 04	12 08 21	12 17 33	AJ	-35R	40	29U	21	799	15	9.1
35	86 09 04	14 12 00	14 21 36	AJ	-50L	80	52U	20	881	11	7.8
36	86 09 05	05 04 55	05 13 37	AJ	185L	45	36U	20	596	13	9.7
37	86 09 05	07 12 04	07 16 02	AJ	-110R	45	44	20	330	10	8.0
38	86 09 05	13 16 19	13 27 30	AJ	-45R	70	37U	20	421	12	8.5
39	86 09 07	11 27 31	11 36 43	AJ	-35R	40	27U	25	593	13	10.1
40	86 09 07	13 28 47	13 39 53	AJ	-55L	75	28U	27	1120	11	8.1
41	86 09 11	03 45 55	03 53 12	AJ	195L	50	50	20	760	11	8.3
42	86 09 11	05 45 16	05 55 03	AJ	-100R	55	37U	21	1293	11	7.3
43	86 09 11	09 52 18	10 02 23	AJ	-35R	35	23U	20	1425	11	6.6
44	86 09 11	11 54 37	12 06 51	AJ	-45R	85	30U	20	866	14	12.7
45	86 09 22	01 52 52	02 06 18	AJ	-125R	80	22U	20	1536	15	9.6
46	86 09 22	03 57 47	04 07 37	AJ	-70R	35	23U	20	780	11	8.0
47	86 09 22	08 06 16	08 17 08	AJ	-40R	55	32U	20	1637	11	7.1
48	86 09 22	10 07 14	10 18 39	AJ	-65L	50	26U	20	1479	11	7.6
49	86 09 24	06 16 31	06 26 41	AJ	-30R	35	21U	20	937	11	7.9
50	86 09 24	08 18 08	08 31 25	AJ	-45R	80	23U	20	2150	12	8.7
51	86 09 25	07 23 52	07 36 57	AJ	-40R	60	21U	20	1900	11	8.5
52	86 09 25	09 29 56	09 37 47	AJ	-70L	45	40U	21	573	11	8.5
53	86 09 26	00 20 22	00 24 10	AJ	215L	75	34U	73	517	10	8.6
54	86 09 26	06 30 56	06 41 46	AJ	-35R	45	25U	21	1148	11	7.8
55	86 09 26	08 32 59	08 44 34	AJ	-55L	70	29U	22	1347	11	8.6
56	86 09 27	01 27 43	01 39 24	AJ	-100R	50	26U	20	1362	11	7.1
57	86 09 28	23 40 33	23 51 29	AJ	220L	80	39U	20	962	15	8.1
58	86 09 29	01 42 14	01 52 54	AJ	-75R	38	23U	20	1013	12	8.2
59	86 09 29	05 49 49	06 01 51	AJ	-35R	45	22U	20	1423	11	8.5
60	86 09 30	00 54 33	00 59 05	AJ	-95R	50	44	20	299	9	6.6

Table 4. Observations and data evaluation

(8) No.	(9) STN	(10) TMP	(11) PRESS	(12) HUM	(13) IDT	(14) DTS	(15) DTL	(16) COMMENTS
		°C	mb	%	ns	μs	μs	
1	7838	23.2	1007.1	99	7.2	-0.4	-2.3	
2	7838	23.1	1007.5	99	7.2	-0.4	-2.3	
3	7838	26.0	1009.0	90	7.1	-0.5	-2.3	
4	7838	24.7	1009.3	95	7.0	-0.7	-2.3	
5	7838	23.5	1008.9	96	7.3	-0.5	-2.3	
6	7838	23.5	1006.6	97	7.2	-0.5	-2.4	
7	7838	23.5	1006.6	97	7.0	-0.4	-2.4	
8	7838	26.1	1004.2	86	7.0	-0.3	-2.4	
9	7838	24.2	1004.1	94	7.1	-0.3	-2.4	
10	7838	25.2	1003.8	88	6.9	-0.4	-2.4	
11	7838	24.0	1001.8	89	7.1	-0.5	-2.4	
12	7838	23.2	1001.2	94	7.2	-0.5	-2.4	
13	7838	24.3	1000.1	97	7.1	-0.3	-2.5	
14	7838	23.5	998.4	98	7.0	0.0	-2.5	
15	7838	23.6	997.7	96	7.2	-0.2	-2.5	
16	7838	27.7	994.0	87	6.9	-0.2	-2.5	DAYTIME
17	7838	26.5	994.6	88	7.0	-0.5	-2.5	
18	7838	24.9	994.3	94	7.0	-0.2	-2.5	
19	7838	24.9	993.8	91	7.0	-0.5	-2.5	
20	7838	24.1	1006.9	75	7.0	-0.3	-2.6	
21	7838	25.2	1005.4	91	7.2	-0.4	-2.6	
22	7838	25.0	1005.1	95	7.1	-0.6	-2.6	
23	7838	26.4	1002.1	85	7.1	-0.3	-2.6	
24	7838	26.1	1000.7	91	7.3	-0.3	-2.6	
25	7838	21.3	1002.9	87	7.0	-0.4	-2.5	
26	7838	21.5	1002.7	84	7.0	-0.3	-2.5	
27	7838	21.7	1006.4	93	7.1	-0.3	-2.5	
28	7838	25.5	1005.7	83	7.2	-0.2	-2.4	
29	7838	33.6	997.0	48	6.9	-0.7	-2.4	DAYTIME
30	7838	30.9	998.6	50	7.2	-0.7	-2.4	DAYTIME
31	7838	24.1	1001.8	78	6.1	-0.7	-2.4	
32	7838	29.6	1004.2	75	5.9	-0.6	-2.3	DAYTIME
33	7838	29.1	1004.5	73	5.7	-0.7	-2.3	DAYTIME
34	7838	25.9	1006.6	95	6.2	-0.4	-2.3	
35	7838	23.5	1007.1	95	6.0	-0.4	-2.3	
36	7838	29.2	1007.7	81	7.0	-0.4	-2.3	DAYTIME
37	7838	28.7	1007.5	84	7.1	-0.4	-2.3	DAYTIME
38	7838	24.3	1008.9	97	6.8	-0.8	-2.3	
39	7838	24.4	1006.0	81	7.1	-0.3	-2.2	
40	7838	22.8	1006.4	90	7.0	-0.3	-2.2	
41	7838	27.8	1002.7	65	7.1	-0.4	-2.1	DAYTIME
42	7838	27.7	1002.1	67	7.1	-0.5	-2.1	DAYTIME
43	7838	24.3	1003.2	82	7.0	-0.5	-2.1	
44	7838	22.6	1004.0	81	7.0	-0.9	-2.1	
45	7838	26.4	1005.6	65	7.1	-0.3	-1.8	DAYTIME
46	7838	26.3	1005.2	65	7.0	-0.5	-1.8	DAYTIME
47	7838	25.6	1006.5	74	7.1	-0.3	-1.8	DAYTIME
48	7838	22.3	1007.7	90	7.1	-0.5	-1.8	
49	7838	26.6	1007.5	58	7.2	-0.5	-1.7	DAYTIME
50	7838	24.3	1007.7	58	6.9	-0.4	-1.7	DAYTIME
51	7838	23.8	1008.2	70	7.0	-0.5	-1.7	DAYTIME
52	7838	22.5	1009.0	72	7.0	-0.2	-1.7	
53	7838	23.0	1012.1	55	7.2	-0.3	-1.6	DAYTIME
54	7838	23.5	1011.0	70	7.0	-0.5	-1.6	DAYTIME
55	7838	22.3	1011.4	75	7.0	-0.5	-1.6	DAYTIME
56	7838	23.6	1012.3	66	7.1	-0.6	-1.6	DAYTIME
57	7838	24.9	1001.6	63	6.9	-0.2	-1.5	DAYTIME
58	7838	29.0	1000.5	41	7.1	-0.3	-1.5	DAYTIME
59	7838	28.0	998.4	58	7.1	-0.4	-1.5	DAYTIME
60	7838	25.1	1007.4	69	7.2	-0.6	-1.5	DAYTIME

Table 4. Observations and data evaluation

(1) No.	(2) Obs.Time(UTC) date			caught			lost			(3) SAT.	(4)Az. ST	(5)Elev. MX	CT	LT	(6) RTN	(7)Fitting N	RMS
	Y	M	D	h	m	s	h	m	s		°	°	°	°			cm
61	86	10	02	05	11	04	05	21	31	AJ	-35R	50	31U	21	856	13	8.7
62	86	10	03	00	10	01	00	18	37	AJ	-90R	45	39U	20	703	11	8.6
63	86	10	03	04	15	42	04	26	26	AJ	-35R	38	22U	20	805	7	8.2
64	86	10	03	06	16	52	06	30	23	AJ	-50L	80	22U	20	1386	15	11.5
65	86	10	03	23	11	48	23	23	55	AJ	-110R	60	22U	24	1542	11	7.8
66	86	10	04	03	21	28	03	24	00	AJ	-30R	32	21	29	272	9	7.0
67	86	10	07	23	41	48	23	51	53	AJ	-70R	35	21U	20	389	14	10.3
68	86	10	08	05	50	46	06	02	44	AJ	-65L	50	22U	20	553	14	9.5
69	86	10	08	20	44	02	20	56	24	AJ	215L	70	27U	20	1405	14	8.7
70	86	10	09	02	54	57	03	06	03	AJ	-35R	40	22U	21	601	19	10.0
71	86	10	12	19	09	41	19	21	44	AJ	200L	55	23U	20	1036	20	9.2
72	86	10	13	01	21	12	01	30	51	AJ	-25R	35	24U	20	915	9	8.6
73	86	10	13	03	30	37	03	35	10	AJ	-45R	80	58	21	562	10	9.0
74	86	10	13	18	16	58	18	26	45	AJ	175L	35	22U	20	1008	12	7.9
75	86	10	14	02	27	53	02	40	59	AJ	-40R	60	22U	20	1013	16	9.4
76	86	10	14	19	28	53	19	35	40	AJ	220L	85	84	20	504	12	10.0
77	86	10	15	01	34	41	01	46	06	AJ	-35R	45	25U	20	946	11	9.2
78	86	10	15	18	29	18	18	41	16	AJ	200L	60	24U	21	734	14	8.0
79	86	10	16	00	40	16	00	50	02	AJ	-30R	37	22U	23	593	11	8.7
80	86	10	16	02	42	14	02	47	55	AJ	-50L	90	26	88	821	11	8.1
81	86	10	16	19	36	29	19	47	48	AJ	-115R	65	23U	29	1107	12	8.3
82	86	10	16	23	46	08	23	55	08	AJ	-35R	30	21U	21	379	9	8.3
83	86	10	17	03	50	24	03	52	38	AJ	-75L	37	22	31	141	7	7.8
84	86	10	17	18	43	08	18	47	45	AJ	-135R	80	29	78	657	13	10.3
85	86	10	17	20	46	08	20	56	49	AJ	-75R	35	21U	20	616	7	9.6
86	86	10	19	18	57	25	19	08	47	AJ	-110R	60	30U	21	1221	11	9.7
87	86	10	20	01	10	46	01	20	27	AJ	-40R	70	48U	20	671	13	10.0
88	86	10	22	01	22	35	01	24	39	AJ	-50L	75	33	51	203	9	8.9
89	86	10	22	18	17	07	18	28	39	AJ	-110R	60	29U	20	1303	11	9.2
90	86	10	23	00	27	25	00	40	07	AJ	-45R	75	25U	20	1443	12	9.3
91	86	10	30	00	14	33	00	25	33	AJ	-75L	40	21U	21	682	9	8.9
92	86	10	30	17	10	35	17	21	27	AJ	-80R	38	21U	20	984	13	9.3
93	86	10	30	23	20	09	23	28	47	AJ	-60L	60	23U	47	992	11	8.9
94	86	10	31	16	15	37	16	27	34	AJ	-95R	50	23U	20	1340	11	9.7
95	86	11	02	16	31	49	16	40	14	AJ	-75R	35	27U	23	214	9	7.6
96	86	11	03	15	35	38	15	47	07	AJ	-90R	45	23U	20	937	19	9.5
97	86	11	04	12	41	15	12	50	37	AJ	180L	40	29U	21	1017	12	8.3
98	86	11	05	13	45	49	13	59	25	AJ	-130R	80	21U	20	1059	20	10.5
99	86	11	06	12	53	32	13	05	10	AJ	210L	70	30U	20	1576	12	8.6
100	86	11	09	18	23	18	18	33	01	AJ	-35R	40	21U	28	922	11	8.8
101	86	11	10	11	18	37	11	30	31	AJ	190L	50	23U	20	1299	14	9.1
102	86	11	10	19	30	47	19	44	04	AJ	-45R	80	22U	20	1213	14	10.1
103	86	11	17	19	18	50	19	28	35	AJ	-75L	35	21U	22	321	10	9.5
104	86	11	18	10	10	24	10	23	59	AJ	-130R	90	21U	20	1261	15	9.7
105	86	11	18	16	22	17	16	34	00	AJ	-35R	50	22U	22	702	13	9.0
106	86	11	19	09	16	43	09	28	11	AJ	205L	65	21U	29	374	9	10.5
107	86	11	19	11	19	29	11	31	28	AJ	-90R	45	21U	20	498	14	8.5
108	86	11	19	15	28	34	15	39	20	AJ	-30R	40	22U	20	590	13	8.8
109	86	11	21	09	34	19	09	40	02	AJ	-130R	80	55U	46	179	17	10.0
110	86	11	21	11	34	37	11	45	02	AJ	-70R	35	21U	20	751	9	7.3
111	86	11	21	15	41	47	15	54	10	AJ	-40R	55	22U	21	882	19	9.2
112	86	11	25	07	55	56	08	09	13	AJ	215L	75	22U	20	1623	12	8.4
113	86	11	25	10	02	25	10	10	22	AJ	-85R	40	35U	21	53	8	12.7
114	86	11	25	14	08	01	14	17	55	AJ	-35R	45	24U	25	469	12	8.7
115	86	11	26	07	02	22	07	14	11	AJ	195L	50	21U	23	865	19	9.4
116	86	11	26	09	04	06	09	16	53	AJ	-100R	55	21U	20	1299	12	8.4
117	86	11	27	06	10	45	06	19	29	AJ	165L	32	23U	21	442	10	8.8
118	86	11	27	08	09	35	08	23	01	AJ	-120R	75	22U	20	1525	16	9.7
119	86	11	27	14	21	26	14	33	29	AJ	-40R	60	24U	22	878	19	9.7
120	86	11	27	16	23	47	16	33	24	AJ	-70L	45	23U	26	493	12	11.8

Table 4. Observations and data evaluation

(8) No.	(9) STN	(10) TMP	(11) PRESS	(12) HUM	(13) IDT	(14) DTS	(15) DTL	(16) COMMENTS
		°C	mb	%	ns	μs	μs	
61	7838	25.6	1008.2	64	7.1	-0.3	-1.4	DAYTIME
62	7838	24.6	1011.9	71	7.5	-0.5	-1.3	DAYTIME
63	7838	26.0	1009.7	51	7.1	-0.4	-1.3	DAYTIME
64	7838	24.7	1009.3	55	7.1	-0.3	-1.3	DAYTIME
65	7838	20.7	1012.3	61	7.2	-0.5	-1.3	DAYTIME
66	7838	23.3	1011.1	55	7.3	-0.4	-1.3	DAYTIME
67	7838	22.5	1002.5	58	7.2	-0.3	-1.1	DAYTIME
68	7838	25.2	1002.1	46	7.2	-0.3	-1.0	DAYTIME
69	7838	14.7	1009.5	67	7.1	-0.6	-1.0	
70	7838	23.5	1010.8	57	7.0	-0.7	-0.9	DAYTIME
71	7838	15.1	1006.6	80	7.2	-0.3	-0.7	
72	7838	22.6	1008.2	60	7.3	-0.2	-0.6	DAYTIME
73	7838	23.6	1007.3	61	7.2	-0.3	-0.6	DAYTIME
74	7838	14.1	1010.1	74	7.0	-0.5	-0.6	
75	7838	22.4	1011.0	62	7.4	-0.5	-0.5	DAYTIME
76	7838	15.0	1010.0	90	7.5	-0.6	-0.5	
77	7838	22.1	1010.8	64	7.4	-0.5	-0.4	DAYTIME
78	7838	14.7	1009.2	85	7.1	-0.6	-0.4	
79	7838	21.7	1010.6	67	7.2	-0.3	-0.3	DAYTIME
80	7838	24.8	1008.8	43	7.3	-0.3	-0.3	DAYTIME
81	7838	13.9	1009.5	71	7.3	-0.7	-0.3	
82	7838	20.0	1010.8	57	7.4	-0.4	-0.3	DAYTIME
83	7838	22.5	1009.0	45	7.3	-0.5	-0.2	DAYTIME
84	7838	11.3	1015.8	53	7.4	-0.6	-0.2	
85	7838	10.1	1016.2	54	7.1	-0.6	-0.2	
86	7838	10.7	1020.2	60	7.1	-0.4	-0.1	
87	7838	16.1	1022.6	53	7.3	-0.3	-0.1	DAYTIME
88	7838	22.8	1004.9	70	7.1	-0.9	0.0	DAYTIME
89	7838	9.4	1013.2	66	7.3	-0.3	0.0	
90	7838	16.8	1017.3	49	7.3	-0.5	0.1	DAYTIME
91	7838	16.1	1014.1	52	7.2	-0.5	0.3	DAYTIME
92	7838	8.1	1020.2	69	7.0	-0.7	0.3	
93	7838	11.3	1021.7	63	7.2	-0.8	0.3	DAYTIME
94	7838	10.4	1018.6	88	7.2	0.0	0.3	
95	7838	16.7	1011.7	74	7.3	-0.4	0.4	
96	7838	14.4	1006.2	95	7.2	0.1	0.4	
97	7838	13.3	1009.7	75	7.3	-0.4	0.4	
98	7838	10.4	1014.9	70	7.0	-0.4	0.4	
99	7838	10.6	1018.2	67	7.3	-0.5	0.5	
100	7838	12.1	1003.6	70	7.3	-0.6	0.5	
101	7838	10.8	1009.3	69	7.0	-0.4	0.5	
102	7838	11.6	1009.9	63	7.0	-0.5	0.5	
103	7838	9.1	1014.2	69	6.2	-0.2	0.7	
104	7838	11.1	1014.5	78	7.3	-0.5	0.8	
105	7838	10.3	1013.0	71	7.2	-0.4	0.8	
106	7838	11.0	1012.4	75	7.2	-0.5	0.8	
107	7838	10.6	1013.0	74	7.3	-0.6	0.8	
108	7838	9.5	1013.4	71	7.3	-0.6	0.8	
109	7838	11.8	1020.8	79	7.1	-0.3	0.8	
110	7838	9.7	1021.9	87	7.2	-0.6	0.8	
111	7838	9.0	1021.5	84	7.4	-0.4	0.8	
112	7838	19.5	1005.8	68	7.2	-0.4	0.9	DAYTIME
113	7838	17.8	1006.6	70	7.1	-0.4	0.9	
114	7838	15.9	1007.9	55	7.0	-0.6	0.9	
115	7838	11.4	1016.7	49	7.1	-0.4	0.9	DAYTIME
116	7838	8.5	1019.7	54	7.1	-0.6	0.9	
117	7838	12.6	1023.2	52	7.2	-0.3	0.9	DAYTIME
118	7838	8.9	1024.1	66	7.1	-0.2	0.9	
119	7838	5.9	1024.5	77	7.1	-0.5	0.9	
120	7838	6.1	1023.9	77	7.4	-0.4	0.9	

Table 4. Observations and data evaluation

(1) No.	(2) Obs.Time(UTC) date	caught	lost	(3) SAT.	(4)Az. ST	(5)Elev. MX	CT	LT	(6) RTN	(7)Fitting N	RMS
	Y M D	h m s	h m s		°	°	°	°			cm
121	86 11 28	07 18 13	07 28 57	AJ	220L	80	41U	20	714	13	7.9
122	86 11 28	09 19 10	09 30 17	AJ	-80R	40	21U	20	807	9	9.9
123	86 11 30	13 41 59	13 52 51	AJ	-40R	65	29U	25	833	15	11.1
124	86 11 30	15 43 33	15 54 03	AJ	-75L	40	22U	20	475	14	10.6
125	86 12 01	06 37 33	06 48 24	AJ	225L	85	38U	21	801	19	9.3
126	86 12 01	08 39 50	08 47 52	AJ	-75R	37	24U	28	181	7	10.5
127	86 12 01	12 46 59	12 56 30	AJ	-40R	45	22U	32	658	15	10.3
128	86 12 02	05 41 34	05 54 22	AJ	200L	60	22U	20	1023	20	9.0
129	86 12 02	07 44 06	07 56 06	AJ	-95R	45	22U	20	1155	12	8.5
130	86 12 02	11 53 28	12 03 41	AJ	-35R	37	23U	20	609	13	9.9
131	86 12 03	08 54 37	09 03 03	AJ	-55R	30	21U	22	385	7	10.1
132	86 12 05	11 12 54	11 23 25	AJ	-35R	40	23U	21	306	7	11.9
133	86 12 06	06 10 16	06 19 29	AJ	-120R	60	29U	34	155	16	13.3
134	86 12 07	13 28 46	13 40 11	AJ	-65L	50	25U	20	468	18	11.3
135	86 12 08	04 24 02	04 33 28	AJ	210L	70	47U	22	269	11	10.5
136	86 12 08	06 25 48	06 34 11	AJ	-90R	45	31U	25	326	10	10.3
137	86 12 08	10 32 36	10 43 34	AJ	-35R	40	23U	20	332	9	12.1
138	86 12 09	03 31 57	03 38 25	AJ	190L	45	45	24	65	5	10.6
139	86 12 09	05 30 05	05 39 09	AJ	-105R	55	29U	33	299	17	10.5
140	86 12 09	09 38 56	09 48 12	AJ	-30R	33	24U	20	639	9	8.7
141	86 12 10	10 46 56	10 57 19	AJ	-40R	55	28U	26	334	18	9.7
142	86 12 11	03 44 44	03 53 03	AJ	215L	75	60U	22	618	11	8.4
143	86 12 11	05 45 30	05 53 04	AJ	-85R	40	30U	28	153	7	9.5
144	86 12 11	09 51 53	10 03 26	AJ	-35R	45	22U	20	763	11	8.3
145	86 12 12	02 51 49	02 59 06	AJ	180L	50	50U	20	136	7	10.2
146	86 12 12	04 50 17	05 00 04	AJ	-100R	55	31U	25	586	19	9.4
147	86 12 12	08 58 11	09 08 10	AJ	-35R	35	22U	20	1239	12	8.4
148	86 12 15	08 23 51	08 28 03	AJ	-35R	35	35	20	108	7	11.6
149	86 12 15	10 22 15	10 32 11	AJ	-50R	80	47U	21	1017	12	8.8
150	86 12 16	11 29 25	11 38 15	AJ	-70L	38	29U	20	412	10	9.2
151	86 12 17	04 26 32	04 34 16	AJ	-75R	37	33U	20	239	7	11.6
152	86 12 17	08 32 12	08 43 16	AJ	-35R	50	27U	20	1110	12	10.1
153	86 12 17	10 33 08	10 39 15	AJ	-60L	60	23	59	31	7	8.3
154	86 12 19	02 34 47	02 46 31	AJ	-110R	65	30U	20	843	15	10.4
155	86 12 19	04 38 43	04 48 00	AJ	-60R	30	21U	20	528	10	9.7
156	86 12 19	08 45 11	08 57 15	AJ	-45R	70	25U	23	971	19	10.0
157	86 12 20	01 41 07	01 52 31	AJ	-130R	80	36U	20	681	19	10.6
158	86 12 22	01 56 37	02 05 58	AJ	-105R	60	44U	21	422	18	10.9
159	86 12 22	06 03 56	06 12 35	AJ	-35R	32	25U	20	458	7	11.2
160	86 12 22	08 06 46	08 17 32	AJ	-45R	75	39U	20	430	18	11.0
161	86 12 23	01 01 49	01 12 01	AJ	-125R	80	45U	21	308	15	9.0
162	86 12 23	07 12 35	07 22 57	AJ	-40R	55	35U	20	475	14	10.6
163	86 12 23	09 13 04	09 24 29	AJ	-65L	50	25U	20	807	19	9.8
164	86 12 24	00 13 27	00 18 01	AJ	215L	70	54	20	256	7	10.6
165	86 12 24	02 08 26	02 19 37	AJ	-90R	40	24U	20	1070	14	11.3
166	86 12 24	08 17 49	08 31 14	AJ	-55L	75	21U	20	1669	13	9.5
167	86 12 26	00 19 50	00 31 51	AJ	-120R	75	31U	20	962	19	10.8
168	86 12 26	06 31 19	06 42 47	AJ	-40R	55	29U	20	990	19	13.4
169	86 12 26	08 32 09	08 43 54	AJ	-70L	45	21U	20	905	19	11.1

Table 4. Observations and data evaluation

(8) No.	(9) STN	(10) TMP	(11) PRESS	(12) HUM	(13) IDT	(14) DTS	(15) DTL	(16) COMMENTS
		°C	mb	%	ns	µs	µs	
121	7838	15.5	1018.8	53	7.2	-0.5	0.9	DAYTIME
122	7838	10.5	1019.1	74	7.2	-0.5	0.9	
123	7838	7.6	1019.3	67	7.3	-0.3	1.0	
124	7838	6.0	1018.2	72	7.3	-0.3	1.0	
125	7838	14.4	1017.1	52	6.9	-0.2	1.0	DAYTIME
126	7838	11.2	1018.2	57	7.1	-0.4	1.0	
127	7838	9.1	1019.5	65	7.0	-0.3	1.0	
128	7838	14.9	1018.7	66	7.1	-0.2	1.0	DAYTIME
129	7838	12.3	1019.1	75	7.0	-0.5	1.0	DAYTIME
130	7838	9.2	1019.3	88	7.1	-0.4	1.0	
131	7838	13.2	1009.6	87	6.9	-0.4	1.0	
132	7838	8.3	1015.3	73	7.3	-0.4	1.0	
133	7838	15.4	1016.0	61	7.7	-0.6	0.9	DAYTIME
134	7838	6.9	1015.6	59	7.7	-0.3	0.9	
135	7838	13.3	1015.6	49	7.8	-0.3	0.9	DAYTIME
136	7838	13.0	1016.5	53	7.8	-0.2	0.9	DAYTIME
137	7838	7.1	1018.2	70	7.8	-0.3	0.9	
138	7838	16.8	1016.5	59	7.7	0.0	0.9	DAYTIME
139	7838	16.6	1016.1	62	7.6	-0.1	0.9	DAYTIME
140	7838	10.3	1016.7	83	7.7	-0.2	0.9	
141	7838	11.3	1010.8	86	7.8	-0.8	0.8	
142	7838	16.6	1013.8	56	7.8	-0.6	0.8	DAYTIME
143	7838	16.2	1013.8	55	8.0	-0.6	0.8	DAYTIME
144	7838	9.2	1016.0	87	7.6	-0.8	0.8	
145	7838	18.1	1016.7	53	7.6	-0.4	0.8	DAYTIME
146	7838	18.7	1015.8	48	7.7	-0.4	0.8	DAYTIME
147	7838	11.5	1018.0	70	7.7	-0.6	0.8	
148	7838	12.0	1009.0	64	7.5	-0.6	0.8	
149	7838	11.0	1011.9	66	7.3	-0.5	0.8	
150	7838	6.4	1017.5	66	7.6	-0.3	0.8	
151	7838	15.0	1016.8	67	7.5	-0.5	0.7	DAYTIME
152	7838	11.3	1018.5	75	7.5	-0.5	0.7	
153	7838	8.0	1019.0	86	7.7	-0.6	0.7	
154	7838	14.7	997.2	60	7.5	-0.4	0.7	DAYTIME
155	7838	15.1	995.7	51	7.4	-0.3	0.7	DAYTIME
156	7838	9.6	998.5	70	7.5	-0.3	0.7	
157	7838	10.4	1013.1	48	7.3	-0.3	0.6	DAYTIME
158	7838	11.8	1016.0	50	7.4	-0.4	0.6	DAYTIME
159	7838	10.8	1017.8	50	7.5	-0.4	0.6	DAYTIME
160	7838	7.3	1019.5	68	7.4	-0.3	0.6	
161	7838	10.9	1021.0	54	7.5	-0.3	0.6	DAYTIME
162	7838	12.4	1016.2	64	7.7	-0.3	0.6	DAYTIME
163	7838	9.5	1016.7	81	7.6	-0.5	0.6	
164	7838	13.0	1014.3	63	7.5	-0.3	0.5	DAYTIME
165	7838	16.4	1013.4	49	7.5	-0.4	0.5	DAYTIME
166	7838	11.1	1012.8	63	7.5	-0.4	0.5	
167	7838	10.7	1018.6	57	7.5	-0.2	0.5	DAYTIME
168	7838	13.1	1016.8	47	7.6	-0.3	0.5	DAYTIME
169	7838	9.2	1018.7	67	7.5	-0.2	0.5	

人工衛星のドップラー観測による離島の位置決定 1986

SATELLITE DOPPLER POSITIONING OF OFF-LYING ISLANDS IN 1986

This paper is a continuation of the series of report on the satellite Doppler positioning of the off-lying islands in Japan which so far appeared in "Data Report of Hydrographic Observation, Series of Astronomy and Geodesy". The provisional results of the observations made by the JHD in 1986 is given.

Key words : satellite Doppler positioning-marine geodetic controls

水路部では，1980年以降海洋測地網の整備として，人工衛星を利用して本土から遠隔地にある島嶼の経緯度の測定を行っている。本稿では，1986年に実施した米海軍航行衛星による離島の経緯度観測の暫定的な成果について報告する。観測方法，整約方法等については水路部観測報告天文測地編第17号を参照されたい（竹村・金沢，1983）。

米海軍航行衛星の観測から求めた各測点標識位置の成果を第1表に示す。経緯度は下里の本土基準点に基づき，高さは標高である。

Table 1. Summary of the positions of the fiducial markers expressed in the Tokyo Datum by means of the satellite Doppler observations

Station	Marker	ϕ	λ	h
		° ′ ″	° ′ ″	m
壱　岐 (Iki)	G1	33 46 01.996N	129 38 46.626E	32.11
硫黄鳥島 (Io Tori Sima)	H1	27 51 44.976	128 14 11.736	123.59
〃	H2	27 51 51.505	128 14 06.789	68.58
〃	G1	27 52 11.722	128 13 39.199	144.08
〃	G2	27 51 45.286	128 14 11.662	125.57
横当島 (Yokoate Sima)	H2	28 47 38.731	128 59 11.868	21.48
上ノ根嶼 (Kaminone Sima)	H2	28 49 53.989	129 00 19.427	16.16
那　覇 (Naha)	H1	26 14 26.149	127 40 32.296	31.91
美　星 (Bisei)	H0	34 40 35.556	133 34 24.747	513.10
〃	H1	34 40 36.242	133 34 26.102	516.43
築　地 (Tukiji)	H	35 39 41.511	139 46 10.393	40.40
〃	A	35 39 40.018	139 46 06.920	4.57
〃	H1	35 39 39.793	139 46 06.921	3.55

h : the height above the (local) mean sea level

1．概要

1．1　作業経過

1986年に実施した全観測地の配置を第1図に示す。

1月20日の壱岐接食観測に伴い，下里，美星，東京（築地），壱岐において同時観測を実施した。

2月28日の蒲原接食観測に伴い，下里，美星，東京（築地），蒲原において同時観測を実施した。

6月下旬から7月中旬にかけて，下里，那覇，硫黄鳥島において同時観測を実施した。

7月下旬に下里，那覇，横当島，上ノ根嶼において同時観測を実施した。

1．2　主な作業

1．測点標識の設置

測点標識（砲金製直径8 cm）硫黄鳥島(1)，横当島(1)，上ノ根嶼(1)

2．航行衛星の同時観測による経緯度の決定

壱岐，硫黄鳥島，横当島，上ノ根嶼，那覇，美星，築地

3．経緯度測量（地上測量による）

硫黄鳥島(3)

1．3　使用機器等

1．航行衛星受信機　4台

機種　マグナボックス社 MX-1502

機械番号　160，162，163，553（以後それぞれ HD1，HD2，HD3，HD4 と称する）

2．テープ変換器　MFE5000，No. 01219

3．整約プログラム　MAGNET

2．観測

2．1　壱岐観測

観測地点と担当者

下　里：下里水路観測所庁舎屋上（第2図）　澪　雅行（下里水路観測所）

美　星：美星水路観測所庁舎屋上（第3図）　監物邦男，淵之上清二，三宅武治（美星水路観測所）

築　地：水路部構内天測室南　（第4図）　福島登志夫，富井清文（航法測地課）

壱　岐：三等三角点戸屋標石上　（第5図）　竹村武彦，仙石　新，長岡　継（壱岐接食観測班）

観測期間と観測数

	受信機	期	間			受信数
下　里	HD3	1月17日	0900～	1月21日	1620	79 パス
美　星	HD2	1月17日	1100～	1月27日	1600	172
築　地	HD4	1月16日	1350～	1月23日	1340	136
壱　岐	HD1	1月17日	1400～	1月21日	1100	39

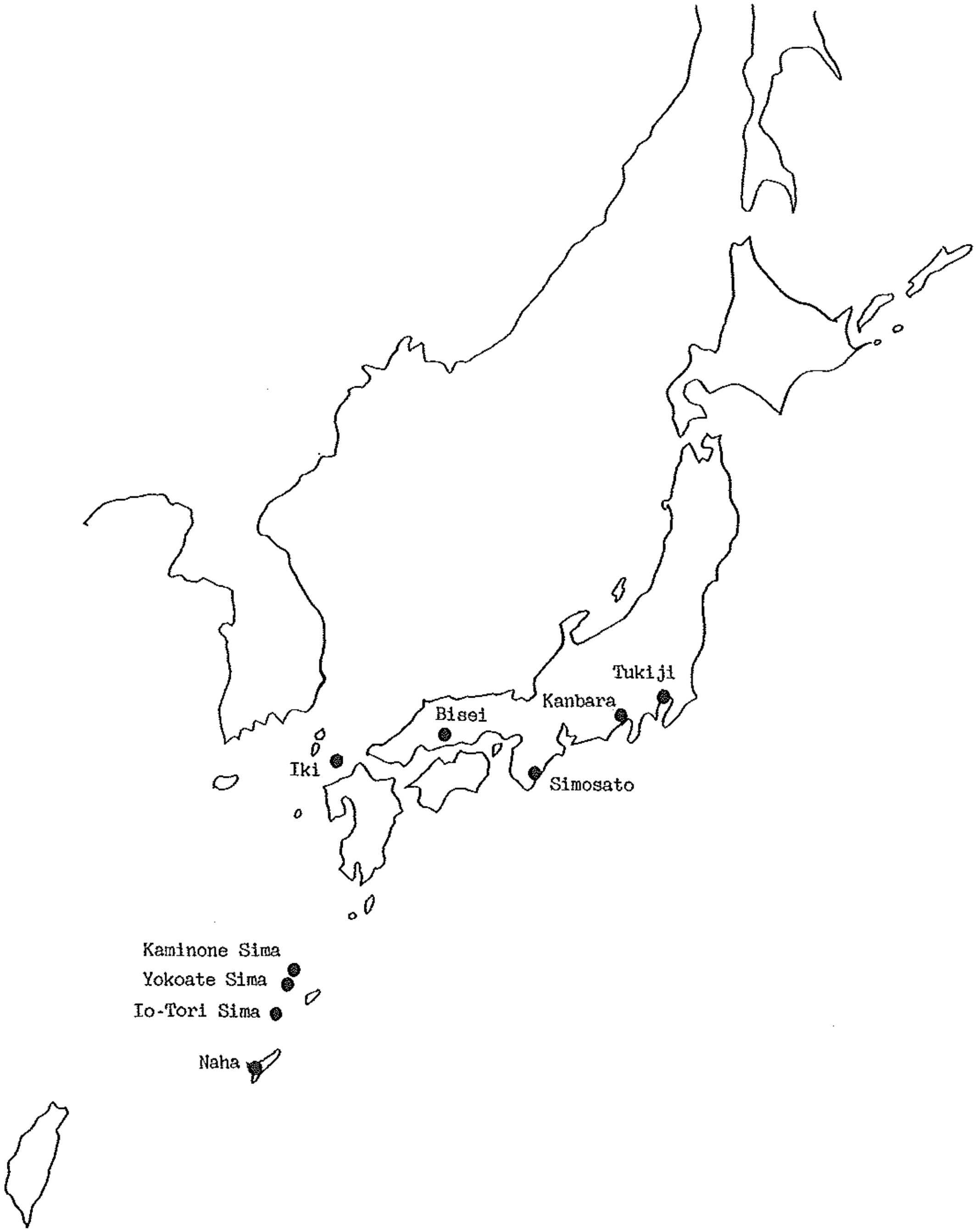

Figure 1. Plan of Doppler positioning in 1986

観測状況と地上測量

下　里：下里水路観測所庁舎屋上のNNSS受信点（第2図N点）において観測した。測点の地上測量は1982年1月に実施した（竹村，1983）。

美　星：美星水路観測所庁舎屋上のNNSS受信点（第3図N点）において観測した。測点の地上測量は1982～1984年に実施した（竹村・監物，1986）。

築　地：1985年11月に水路部構内天測室南に設置した測点標識（H1）上に受信アンテナを設置して観測した。受信アンテナ中心は測点標識上1.90mである。測点標識の地上測量は，天測室内の望遠鏡測台上に設置してある測点標識(A)を原点とし，太陽による方位を基準に実施した。測量作業は1987年5月に長岡継ほか2名が実施した。測点標識Aの地上測量は1975年に実施した（森，1976）。地上測量に基づくAの位置は

$\phi=35°39'40''.048N$　　$\lambda=139°46'06''.858E$　　$h=4^{m}.57$

である。

壱　岐：壱岐南西部の三等三角点戸屋標石上に受信アンテナを設置して観測した。受信アンテナ中心は標石上1.55mである。

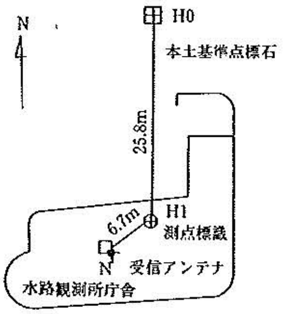

Figure 2. Simosato

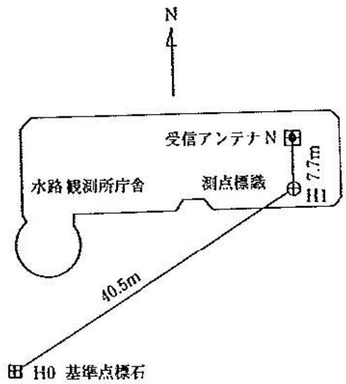

Figure 3. Bisei

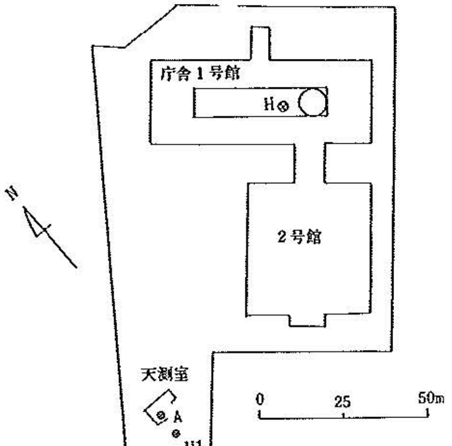

Figure 4. Hydrographic Office(Tukiji)

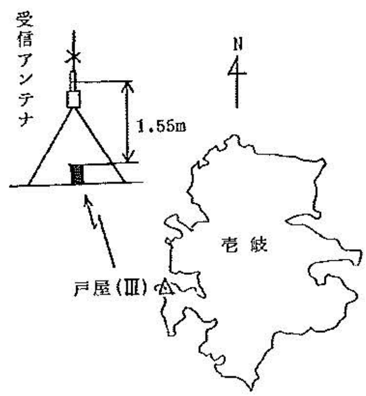

Figure 5. Iki

2．2 蒲原観測

観測地点と担当者

下 里：下里水路観測所庁舎屋上（第２図） 佐々木弘，澤 雅行（下里水路観測所）

美 星：美星水路観測所庁舎屋上（第３図） 監物邦男，淵之上清二，三宅武治（美星水路観測所）

築 地：水路部構内天測室南 （第４図） 竹村武彦，富井清文（航法測地課）

蒲 原：蒲原町立西部保育園 （第６図） 山口正義，井上均見，増山昭博（蒲原接食観測班）

観測期間と観測数

	受信機	期　　間	受信数
下 里	HD3	２月26日 1640～３月４日 0900	115 パス
美 星	HD2	２月25日 1000～３月１日 1030	85
築 地	HD4	２月27日 1500～３月３日 1300	74
蒲 原	HD1	２月27日 1010～３月１日 1150	40

観測状況と位置測量

下里，美星，築地における観測状況は２．１の壱岐観測と同様である。ただし，築地における受信アンテナ中心位置は測点標識上1.96m である。

蒲 原：蒲原町立西部保育園のプレハブ倉庫の屋上に受信アンテナを設置して観測した。近傍の三角点との結合測量は実施しなかった。

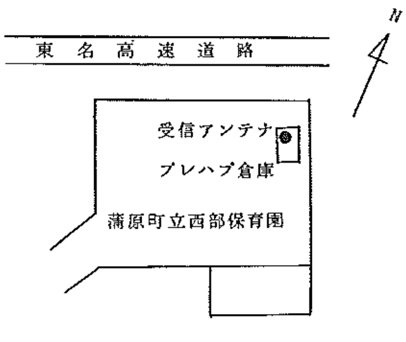

Figure 6. Kanbara

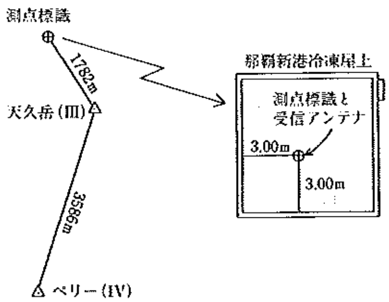

Figure 7. Naha, Okinawa Sima

2．3　硫黄鳥島観測

硫黄鳥島は徳之島北西端の西方約65kmにある無人の火山島で，北北西・南南東方向の長さが約2.8km，幅約1.3kmあり，周囲は険しいがけである（第8図）。本観測は，沿岸調査課が実施した離島海の基本図「硫黄鳥島」測量及び「硫黄鳥島」沿岸流観測と併行して実施した。本観測には測量船拓洋を使用した。

この島における測点標識の設置経過は以下のとおりである。

島　嶼		設置年月日	設 置 者	所 属	使用船(機)
硫黄鳥島	H1	1978．8．24	測量船明洋乗組員	水路部	HL03 明洋
〃	H2	1986．6．29	長岡　繇	航法測地課	HL02 拓洋

観測地点と担当者

下　　里：下里水路観測所庁舎屋上（第2図）　小山　薫，佐々木弘，澤　雅行
（下里水路観測所）

那　　覇：株式会社那覇新港冷凍屋上（第7図）　第十一管区水路課職員

硫黄鳥島：測点標識 H2 近傍　（第8図）　長岡　繇（離島測地観測担当）

観測期間と観測数

	受信機	期　　間	受信数
下　　里	HD3	6月25日　1800～7月 3日　1730	154 パス
〃	〃	7月11日　0900～7月15日　0900	75
那　　覇	HD2	6月25日　1400～7月 2日　1600	132
〃	〃	7月11日　0900～7月14日　1600	101
硫黄鳥島	HD4	6月28日　1500～7月 1日　1900	57
〃	HD1	7月11日　1500～7月14日　1500	55

観測状況と地上測量

下　　里：下里水路観測所庁舎屋上のNNSS受信点において観測した。硫黄鳥島の観測に合わせて途中一時中断した。

那　　覇：株式会社那覇新港冷凍屋上の水路部測点標識上に受信アンテナを設置して観測した。受信アンテナ中心は測点標識上2.00mである。測点標識の地上測量は1980年12月に十一管区水路課職員が三等三角点天久岳を原点に，四等三角点ペリーを方位基準にして実施した（竹村・金沢，1983）。

硫黄鳥島：島南東部の崖上に受信アンテナを，その近傍に測点標識 H2 を設置して下里，那覇との同時観測を実施し，受信アンテナ位置を求めた。アンテナ中心位置と，太陽による真方位を基準にして，水路部測点標識 H1，H2，国土地理院の一等三角点 G1，二等多角点 G2 の位置を測量により求めた。NNSS 観測は，台風接近に伴う避航のため，観測機器を一時撤収して現地を離れたので，作業期間が前後二期に分かれた。NNSS に基づくアンテナ位置は前期，後期の観測を別々に整約し，それらの結果の平均値を採用した。

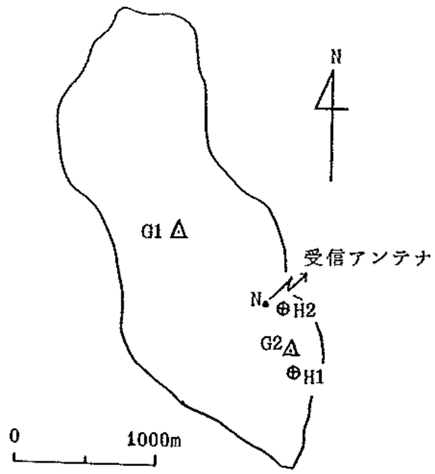

Figure 8. Io-Tori Sima

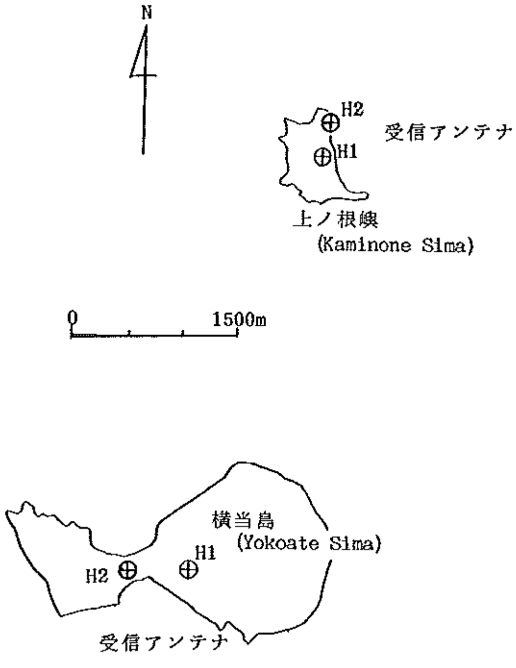

Figure 9. Yokoate Sima, Kaminone Sima

2．4　横当島，上ノ根嶼観測

横当島は宝島の南西約46kmにある小さな無人島で，東と西にはっきりした頂がある。上ノ根嶼は横当島北方約4kmにある更に小さな無人島である（第9図）。本観測は，沿岸調査課が実施した離島海の基本図「横当島」測量及び「横当島」沿岸流観測と併行して実施した。本観測には測量船拓洋を使用した。

これらの島における測点標識の設置経過は以下のとおりである。

島　嶼		設置年月日	設　置　者	所　属	使用船(機)
横 当 島	H1	1978．8．23	測量船明洋乗組員	水路部	HL03 明洋
	H2	1986．7．9	長岡　継	航法測地課	HL02 拓洋
上ノ根嶼	H1	1978．8．27	測量船明洋乗組員	水路部	HL03 明洋
	H2	1986．7．24	長岡　継	航法測地課	HL02 拓洋

観測地点と担当者

下　　里：下里水路観測所庁舎屋上（第2図）　小山　薫，佐々木弘，澤　雅行（下里水路観測所）

那　　覇：株式会社那覇新港冷凍屋上（第7図）　第十一管区水路課職員

横 当 島：測点標識 H2 上　（第9図）　長岡　継（離島測地観測担当）

上ノ根嶼：測点標識 H2 上　（第9図）　長岡　継（離島測地観測担当）

観測期間と観測数

	受信機	期　　間	受信数
下　　里	HD3	7月19日 1230～7月28日 1700	179 パス
那　　覇	HD2	7月21日 1230～7月28日 1600	165
横 当 島	HD1	7月21日 1530～7月27日 1750	101
上ノ根嶼	HD4	7月24日 1130～7月27日 1830	56

観測状況

下里，那覇における観測状況は2．3の硫黄鳥島観測と同様である。

横 当 島：島の鞍部に測点標識 H2 を設置し，測点標識上に受信アンテナを設置して観測した。アンテナ中心は測点標識上1.62mである。

上ノ根嶼：島北東部の崖の上に測点標識 H2 を設置し，測点標識上に受信アンテナを設置して観測した。アンテナ中心は測点標識上1.53mである。

3．成果

受信データを MAGNET プログラムにより整約し，受信アンテナ位置を WGS72 の楕円体上で求めた結果を第 2 表に示す。これらの観測成果を日本測地系に変換したものが第 3 表で，それぞれの同時観測結果に対し，変換に使用したパラメータの値も掲げた。いずれも高さは楕円体上の高さを表わす。

Table 2. Positions of the NNSS antennas : the solutions of the translocation of the Doppler observations in the reference system of NNSS

Station	φ	λ	H	Note
	° ′ ″	° ′ ″	m	
下　里 (Simosato)	33 34 39.123N	135 56 12.089E	107.19	壱岐観測
美　星 (Bisei)	34 40 47.867	133 34 15.743	553.08	
築　地 (Tukiji)	35 39 51.352	139 45 54.490	41.13	
壱　岐 (Iki)	33 46 13.435	129 38 37.674	64.43	
下　里 (Simosato)	33 34 39.242	135 56 12.109	106.60	蒲原観測
美　星 (Bisei)	34 40 47.975	133 34 15.798	552.49	
築　地 (Tukiji)	35 39 51.456	139 45 54.528	41.42	
蒲　原 (Kanbara)	35 06 58.033	138 34 59.233	57.52	
下　里 (Simosato)	33 34 39.038	135 56 11.887	105.36	硫黄鳥島観測 前半
那　覇 (Naha)	26 14 40.359	127 40 24.420	65.80	
硫黄鳥島 (Io Tori Sima)	27 52 05.160	128 13 58.279	102.54	
下　里 (Simosato)	33 34 38.818	135 56 11.921	109.28	硫黄鳥島観測 後半
那　覇 (Naha)	26 14 40.147	127 40 24.492	68.60	
硫黄鳥島 (Io Tori Sima)	27 52 04.958	128 13 58.372	105.39	
下　里 (Simosato)	33 34 39.196	135 56 11.962	108.27	横当島・上ノ根嶼 観測
那　覇 (Naha)	26 14 40.521	127 40 24.481	66.68	
横当島 (Yokoate Sima)	28 47 52.200	128 59 03.460	55.36	
上ノ根嶼 (Kaminone Sima)	28 50 07.444	129 00 11.010	50.13	

H : the height above the WGS-72 ellipsoid (a=6378135m, f=1/298.26)

Table 3. Positions of the NNSS antennas : the transformed results of Table 2 into the Tokyo Datum

Station	φ	λ	H	translation parameters	Note
	° ′ ″	° ′ ″	m	m	
下　里☆	33 34 27.098N	135 56 23.041E	67.61	ΔU= 133.935	壱岐観測
美　星	34 40 36.497	133 34 26.082	497.24	ΔV=−522.654	
築　地	35 39 39.800	139 46 06.915	4.69	ΔW=−676.591	
壱　岐	33 46 01.996	129 38 46.626	0.17		
下　里☆	33 34 27.098	135 56 23.041	67.61	ΔU= 132.484	蒲原観測
美　星	34 40 36.485	133 34 26.121	497.18	ΔV=−520.532	
築　地	35 39 39.785	139 46 06.926	5.40	ΔW=−679.320	
蒲　原	35 06 46.261	138 35 11.188	19.79		
下　里☆	33 34 27.098	135 56 23.041	67.61	ΔU= 130.258	硫黄鳥島観測
那　覇	26 14 26.157	127 40 32.297	47.90	ΔV=−526.345	前半
硫黄鳥島	27 51 51.546	128 14 06.447	74.43	ΔW=−673.397	
下　里☆	33 34 27.098	135 56 23.041	67.61	ΔU= 135.908	硫黄鳥島観測
那　覇	26 14 26.144	127 40 32.301	46.12	ΔV=−530.593	後半
硫黄鳥島	27 51 51.547	128 14 06.473	72.86	ΔW=−669.918	
下　里☆	33 34 27.098	135 56 23.041	67.61	ΔU= 131.410	横当島・上ノ根嶼
那　覇	26 14 26.146	127 40 32.290	46.76	ΔV=−524.769	観測
横 当 島	28 47 38.731	128 59 11.868	20.85	ΔW=−679.062	
上ノ根嶼	28 49 53.989	129 00 19.427	15.41		

H : the height above the reference ellipsoid of the Tokyo Datum
☆ shows the fixed station to derive the corresponding translation parameters. The coordinates of this station were obtained by the previous Doppler observations and the ground surveys.

初めに掲げた第1表は，第3表に示した受信アンテナの位置に基づく測点標識等の位置である。ただし，結果が複数個ある地点については，それらの平均値を用いた。

Table 4. Positions of the NNSS antennas : the ground survey results in the Tokyo Datum or in the local datum

Station	φ	λ	h	Note
	° ′ ″	° ′ ″	m	
下　里☆	33 34 27.098N	135 56 23.041E	67.61	壱岐観測
美　星	34 40 36.418	133 34 26.019	518.26	
築　地	35 39 39.822	139 46 06.859	5.46	
壱　岐	33 46 01.878	129 38 46.647	33.66	
下　里☆	33 34 27.098	135 56 23.041	67.61	蒲原観測
美　星	34 40 36.418	133 34 26.019	518.26	
築　地	35 39 39.822	139 46 06.859	5.51	
蒲　原	—	—	—	
下　里☆	33 34 27.098	135 56 23.041	67.61	硫黄鳥島観測
那　覇	26 14 26.582	127 40 32.046	33.91	前半
硫黄鳥島	27 51 51.922	128 14 06.185	70.06	
下　里☆	33 34 27.098	135 56 23.041	67.61	硫黄鳥島観測
那　覇	26 14 26.582	127 40 32.046	33.91	後半
硫黄鳥島	27 51 51.922	128 14 06.185	70.06	
下　里☆	33 34 27.098	135 56 23.041	67.61	横当島・上ノ根嶼
那　覇	26 14 26.582	127 40 32.046	33.91	観測
横 当 島	—	—	23.10	
上ノ根嶼	—	—	17.69	

h : the height above the (local) mean sea level

☆ : Defining values of the coordinate system adopted by this series of report (expressed in the Tokyo Datum)

Table 5. Differences between the Doppler results and the survey results : Doppler (Table 3) minus survey (Table 4)

Station	△ φ	△ λ	hg
	″	″	m
下　里 (Simosato)	0.000	0.000	0.00
美　星 (Bisei)	+0.073	+0.083	−21.05
築　地 (Tukiji)	−0.030	+0.062	−0.44
壱　岐 (Iki)	+0.118	−0.021	−33.49
那　覇 (Naha)	−0.433	+0.250	+13.02
硫黄鳥島 (Io-Tori Sima)	−0.376	+0.275	+3.59
横当島 (Yokoate Sima)	—	—	−2.25
上ノ根嶼 (Kaminone Sima)	—	—	−2.28

hg : geoidal height referred to reference ellipsoid of the Tokyo Datum or local datum

Table 6. Positions of the reference triangulation points used for the survey (expressed in the Tokyo Datum or in the local datum)

Station		φ	λ	h
		° ′ ″	° ′ ″	m
下　里	高芝 (III)	33 34 36.058N	135 54 58.502E	123.35
〃	太地 (II)	33 34 51.295	135 56 37.380	79.57
美　星	大倉牧場 (IV)	34 40 35.610	133 34 24.201	513.46
〃	仏の峠 (III)	34 41 05.074	133 34 23.529	504.15
築　地	台場 (III)	35 37 50.603	139 46 34.542	9.64
壱　岐	戸屋 (III)	33 46 01.878	129 38 46.647	32.11
那　覇	天久岳 (III)	26 13 37.292	127 41 05.766	45.85
〃	ペリー (IV)	26 11 46.784	127 40 24.714	48.01
硫黄鳥島	G 1 (I)	27 52 12.097	128 13 38.924	143.89
〃	G 2 (II多)	27 51 45.661	128 14 11.387	125.38

The Roman number denotes the class of the triangulation points.

本報告は，竹村武彦が作成し，電子計算機による観測成果の算出は長岡　継が担当した。

参　考　文　献

竹村武彦・金沢輝雄，1983：水路部観測報告天文測地編，17，61.

竹村武彦，1983：水路部観測報告天文測地編，17，44.

竹村武彦・監物邦男，1986：水路部観測報告天文測地編，20，68.

森　　巧，1976：水路部観測報告天文測地編，10，42.

ドップラー観測による離島の位置決定に関する従前の報告は以下の水路部観測報告に収録してある.

竹村武彦・金沢輝雄，1983：水路部観測報告天文測地編，17，61.

竹村武彦・金沢輝雄，1984：水路部観測報告天文測地編，18，42.

竹村武彦，1985：水路部観測報告天文測地編，19，85.

竹村武彦，1986：水路部観測報告天文測地編，20，72.

訂正　1986：水路部観測報告天文測地編第20号

P75，1行　1982年4月 を 1983年11月 にする。

P77，24行　$\triangle\phi=+0\farcs003$　$\triangle\lambda=+0\farcs004$　$\triangle h=+1\overset{m}{.}75$ を

$\triangle\phi=+0\farcs678$　$\triangle\lambda=+0\farcs116$　$\triangle h=+5\overset{m}{.}52$ にする。

P84, Table 7, 5行　男島 を 鳥島 にする。

1983：水路部観測報告天文測地編第17号

P45, Table 2, 12行　$68\overset{m}{.}07$ を $58\overset{m}{.}07$ にする。

COMPLETION OF A TRANSPORTABLE LASER RANGING STATION (HTLRS)

Abstract

A Transportable Laser Ranging Station for the project of the expansion of the Marine Geodetic Controls around Japan had been manufactured since 1985 and was completed by the end of October 1987.

The Nd:YAG laser subsystem transmits pulses of 50–100 psec width in the repetition rate of 5 pps. The output energy of each pulse is around 50 millijoules.

The receiving optics, electronics and elevation axis are on a bench gimballed on the azimuth axis. The transmitter laser beam of 10 cm diameter passed along the azimuth axis is transmitted to a satellite by using the central part of a square mirror for elevation control. The return signal from the satellite is also received by the outer part of the same mirror for elevation control and is guided to the Cassegrain receiver with 35 cm aperture.

All the system is housed in two shelters. The mount and laser subsystem are installed in one of the shelters and control/measurement electronics are set up in the other shelter. The total weight is about 5 tons and the system can be transported by a ship or a transport plane.

The system can measure the timing of flickers of reflected solar light from the Japanese Geodetic Satellite "Ajisai" by using the same receiving optics for laser ranging except the final stage for detection. The timing data are used for photographing of the satellite by a transportable satellite camera. The station is capable of ranging not only to Ajisai but also Lageos. Test observations and total adjustments of the HTLRS started in September 1987 at the Simosato Hydrographic Observatory. The ranging precisions for Ajisai and Lageos given by the test observations are 3 – 4 cm level. The specifications of the HTLRS are given in this report.

Key words: satellite laser ranging – TLRS

1. System configurations

A Transportable Laser Ranging Station of the Hydrographic Department was completed in October 1987 and named as HTLRS. The station has been manufactured since 1985 and is to be used for the precise determination of position of off-lying islands in the project named the expansion of the Marine Geodetic Controls around Japan. The station is composed of the following subsystems; (1) a laser subsystem, (2) a mount, (3) transmitting optics, (4) receiving optics, (5) receiving electronics, (6) a control subsystem, (7) a clock subsystem, (8) a computer subsystem, (9) timing measurement subsystem for the reflected solar flicker light from "Ajisai", (10) meteorological measurement equipments, (11) shelters and (12) power generators. The overview of the HTLRS is given in Figure 1 and the control-, computer- and clock subsystems are shown in Figure 2.

2. A laser subsystem

The laser is a frequency doubled and mode locked Neodymium YAG (Nd:YAG) system (Quantel International YG 501C) that produces a pulse of 50 millijoules (mJ) energy and 50 – 100 ps width with a repetition rate of 5 pps. The laser subsystem consists of a transmitter assembly, a laser control console with power supplyer and a heat exchanger. The transmitter assembly is located on the laser table under the mount in one of the shelters and the control console and the heat exchanger are housed in the other shelter.

The transmitter assembly consists of a pumping oscillator followed by a pulse slicer, one stage of a double-passing pumping laser amplifier and an optical second-harmonic generator. The oscillator transmits a mode-locked pulse train which includes seven to nine pulses of 7.5 ns interval and the slicer selects one pulse from the pulse train. The selected narrow pulse is amplified by the double-passing amplifier. The output pulse width can be selected as 35 ps, 50 ps, 100 ps or 200 ps. The maximum output energy for the case of 200 ps pulse width is 70 mJ in the wavelength of 532 nm. The diameter of the output laser beam is 7 mm and the stability of the output energy is around 7% RMS. The beam divergence is 0.6 mrad and polarization is perpendicular. The time jitter is around 10 μs. The optical block diagram of the laser transmitter assembly is given in Figure 3.

The oscillator and amplifier are illuminated by two and four flash lamps, respectively. To release the heat from these flash lamps the subsystem has a water-circulating cooling unit. The volume of the circulating water is 7.6 l/min. The heat of the water is released to the outside of the shelter by two air conditioners.

3. Mount

The mount has a form of a gimballed elevation axis over the azimuth axis. The transmitting optics, receiving optics and major part of receiving electronics are on a bench over the azimuth axis. A transmitter laser pulse passed along the azimuth axis is transmitted to a satellite by using the central part of a square mirror for elevation control. A returned signal from the satellite is also received by the outer part of the same mirror for elevation control. The optical block diagram of the system is shown in Figure 4. The elevation axis is driven by a DC-torque motor (Magnedyne R9223-01-T with 295 Watts) and controlled by both a tachometer (Magnedyne T9224-100-P) and a 20 bits encoder (Tamagawa-Seiki TS1303N50) with a resolution of 1.2 arcsec. For the azimuth axis, a DC-torque motor (Magnedyne RE10428-04-T with 325 Watts), a tachometer (Magnedyne T9224-100-P) and a 20 bits encoder (Tamagawa-Seiki TS1303N50) are used. The ranges of the azimuth and elevation axis are ±300 deg and –96 deg to +91 deg, respectively. The tracking angular velocities are from sidereal to 13 deg/s both for elevation and azimuth. The estimate of the tracking accuracy is within 10 arcsec.

4. Transmitting optics

The laser pulse beam transmitted from the transmitter subsystem with the diameter of 7 mm is expanded to 10 cm by a beam divergence control and is reflected into a Coude path along to the azimuth axis by a mirror. The pulse is also reflected by a mirror at the center of receiving optical path and by the central part of elevation control mirror. At the front end of transmitter/receiver a high precision flat coverglass is equipped. Total loss estimate for transmitter light is about 6%. A corner cube prism for alignment and mirror adjustment is attachable in front of the coverglass. A He-Ne laser for collimation is also applicable for a beam alignment.

The divergence for output laser light is controlled from 80 μrad to 2.0 mrad by a motor driven lens positioner.

For the case of ground target ranging for calibration, a pinhole attenuator for output laser light is inserted after the beam expander/divergence control.

5. Receiving optics

A returned light from a satellite is guided to a Cassegrain telescope (a modified Celestron C–14 by Yukigaya-Seimitsu) after reflection by the flat square mirror with the size of 35 cm x 50 cm. The aperture of the telescope is 35 cm and the focal length is 3.9 m. The first mirror is made of aluminum and the shadow of the second mirror of the telescope is well used for light path of transmitting pulse. The parallel light beams to the optical axis of the telescope make a point image at the focus where a remote controlled iris limits the field of view with a range from 100 μrad to 5 mrad.

The light is splitted to two ways by using a dicroic mirror with 99.5% reflectivity for 532 nm. The light with the wavelength near 532 nm goes to a micro-channel-plate photomultiplier tube (MCP–PMT: Hamamatsu R2024U-01 with gating function) through a remote controlled optical attenuator with range from 0 to 40 dB, a mechanical chopper to protect the PMT from the strong scatter transmitting light and an interference filter with 1.0 nm bandpass and 45% transparency. This green light is also guided to an eyepiece. The course of the remaining splitted light without green spectrum is changed by some mirrors. In one case all the remaining light goes to a television guide with an image intensifier with 6.5 star magnitude tracking capability. In another case the light goes to a photomultiplier tube (Hamamatsu R669) for detection of the timing of flickers of reflected solar light from the Japanese Geodetic Satellite "Ajisai". The timing data are used for photographic direction determination of the satellite by using a transportable satellite camera (Sasaki, M., Hashimoto, H., 1987). Both reflected light and transparent light by the dicroic mirror can be seen through two respective eyepieces.

6. Receiving electronics

The start pulse is detected by a photodiode (Hamamatsu S-2381 with 200 ps risetime) at just after the laser transmitter. The receiving electronics to detect the returned signal and to measure the flight time consists of the MCP–PMT, two amplifiers (NEPA 1001AA with 50 MHz – 3 GHz bandpass and 20 dB gain, each), a fast dual comparator (Plessey SP9687), a receiver control unit and a flight time counter with 20 ps resolution (HP 5370B). The PMT has a gain of 5×10^{-5} and a rise time of 300 ps. The quantum efficiency of the PMT is 6% at 532 nm of the wavelength. The position and width of range gate are controled within the range from 0.6 μs to 0.1 s and from 200 ns to 30 ms, respectively. The receiving electronics can detect one electron signal level.

7. Control subsystem

The mount is controlled by a survo controller and amplifier according to computer output values at the I/O rate of 20 Hz.

The following items are remotely controlled through the console panel and control unit: satellite tracking and ranging; ground target ranging; star tracking for mount calibration; joystic control of the mount (manual and computer aided); optical receiver attenuation (0 – 40 dB); start and stop threshold level; system clock adjustment; shutter for input light; range gate width (200 ns – 30 ms with 1 μs interval) and gate position control (0.6 μs – 0.1 s in 2 μs interval); tracking time offset, manual motion of the mount, transmit laser beam divergence (80 μrad – 2.0 mrad), field of view (100 μrad – 5 mrad).

The following items are displayed on the console panel: elevation and azimuth encoder bits (20 bits x 2); elevation and azimuth angle in degree; time; start and stop thresholds; field of view; beam divergence; conductivity of cooling water; shutter status; detected flash timing of Ajisai; wave form of transmitted laser light. On a CRT screen elapsed time after tracking start, predicted and actual elevation and azimuth angles, additional values for elevation and azimuth by joystic control, observed range (O) and observed minus calculated (O–C) range values and number of return signals. Some of these values are given by pictures and the tracking to satellite can be made by a computer game like operation.

8. Clock subsystem

The clock subsystem includes a Rubidium frequency standard (NEC Rb-3100), a digital clock (Kokusai KPM-3930), a Loran C receiver (Koden LR-787), a Loran C simulator/ transmitter (Koden LSR-128), a counter (Iwatsu SC-7201), a oscilloscope (Hitachi V-212), a JJY receiver, a printer/recorder and its interface and battery power supply.

The frequency standard supplies a 5 MHz signal with the stability of 2×10^{-11}. The delaytime in the Loran C receiver is calibrated by the Loran C simulator/transmitter and receiver. The cycle time of Loran C, for instance 99.7 ms for the Northwest Pacific Loran C chain, can be adjustable for any other cycle times.

9. Computer

Hitachi B16/FX (8087) microcomputer with a 5 inch- and two 3.5 inch-floppy disks is used as the computer for system control and satellite ephemeris calculation. The peripheral devices are a hard disk, a printer and a CRT display.

To record the timings for Ajisai flashing another Hitachi B16/FX (8086) microcomputer is used. As the software the programs for those for the former fixed SLR system (Sasaki *et al.*, 1983, Sasaki M., 1983) installed at the Simosato Hydrographic Observatory are used with some improvement. Some of the status of the system and computed results are shown on CRT colorfully and in picture. The calculation speed is also improved compared with the computer of the former fixed system. For telephone line communication, a modem with 300/1200 baud rates (Hitachi HP-120F) is prepared.

10. Ajisai timing record subsystem

The brightness of the Ajisai flashing is from 4.5 to 1.0 star magnitude. The timings for both risetime and falltime of Ajisai flashing are measured by the other PMT and the timing is recorded by another timing unit for this purpose. In this timing unit amplifier of detected signal and time latch mechanism are included. The threshold for timing signal level can be adjustable. The field of view is controlled in the range from 100 μrad to 5 mrad. The maximum data record rate is 4 pps and all the timings are recorded on a floppy disk. The precision of these timings is 50 μs. The each time of Ajisai flash can be observed by a monitor lamp on the console panel with sound.

11. Meteorological equipments

As the meteorological equipments a thermometer for the range from −20 deg C to 40 deg C with the accuracy of 1 deg C and a humidity meter (Oota-Keiki TH-85), an Assmann humidity meter for calibration, an Aneroid pressure meter for the range from 740 mb to 1045 mb and wind direction and speed meter are prepared. These equipments are set up outside of the shelters.

12. Shelters

Most part of the system is included in two shelters. The mount and laser subsystem are installed in one of the shelters and the control/measurement electronics are set up in the other shelter. The shelter protects the system from water, rain, high humidity, salinity and high and low temperature. The temperature in the shelter is maintained at 20 deg C and humidity is under 65% by using air conditioners. The air conditioners (Hitachi RA4503T with heater WH 403P) are equipped in the control/electronics shelter. The consuming power is 1.9 kW for cooling and 4.2 kW for heating. The shelters are made of aluminum mainly. The size is 2.1 m x 2.3 m x 3.5 m for mount/optics/laser part and 2.1 m x 2.3 m x 3.8 m for the other shelter. The total weight of all the system is around 5 tons. The system housed in the shelters can be transported by a ship or an transport plane.

13. Power generators

The system has two power generators. They are on two carts. The output power is 20 kW in AC 200V (Denyo DCA-25) and 7.5 kW in AC 100V (Denyo DCA-10SPX) each with 50 Hz. The total weight of the two generator is 1310 kg. The quantity of the oil consuming is about 9 l/h for both.

The total specifications of the HTLRS are given in Table 1.

14. Miscellaneous

Test observations and total adjustments of the HTLRS has been started and continued from September 1987 at the Simosato Hydrographic Observatory. Two ground targets are used for the system calibration. The position of a brass marker under the HTLRS set in September 1987 is 33°34′26.″2895N (lat.), 135°56′23.″5855E (lon.) and 57.587 m hight in the Tokyo Datum.

The HTLRS is capable of ranging both to Lageos and Ajisai. The range precisions for both satellites given by the test observations are 3 – 4 cm level.

The HTLRS will be shipped to Titi-shima in Ogasawara (Bonnin) islands in late December 1987 and field satellite observations will start in mid-January 1988. A precise report for the test observations and satellite observations in the fields to establish the marine geodetic controls will be made later.

This report was compiled by M. Sasaki of the Geodesy and Geophysics Division.

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Table 1. Specifications of the Hydrographic Department Transportable Satellite Laser Ranging Station (HTLRS)

Subsystem	Specification
Laser	
Oscillator	mode-locked Nd:YAG with an amplifier
Wavelength	532 nm
Output energy	50 mJ
Pulse width	50 – 100 ps
Repetition rate	5 pps
Mount	
Configuration	elevation over azimuth/Coude path
Tracking rate	from sidereal to 13 deg per second
Angular resolution	20 bits (1.2 arcsec)
Tracking accuracy	less than 10 arcsec
Transmitter/receiver optics	
Type	a common flat plate for elevation control
Telescope	Galilean for transmitter and Coude for receiver
Diameter	10 cm for transmitter and 35 cm for receiver
Beam divergence	80 μrad – 2 mrad
Field of view	0.1 – 5 mrad
Spectral filter	1.0 and 3.0 bandpass (changeable)
Optical attenuator	0 – 40 dB
Electronics	
Start pulse detector	photo diode with 200 ps rise time
Receiving detector	Micro-Channel-Plate PMT with 300 ps rise time
Discriminator	fast dual comparator
Flight time counter	20 ps resolution
Range gate	0.6 μs – 0.1 s shift with 200 ns – 30 ms width
Control	
Mount control	DC servo using torque motor/tachometer/encoder
Data flow rate	20 Hz between a computer and a servo system
Clock	
Frequency standard	a Rubidium oscillator with 2×10^{-11} rate
Comparison	multi-Loran C wave
Computer	
CPU	two 16 bits micro computer
Peripherals	a hard disk, a 5 inch- and two 3.5 inch-floppy disks, printer/recorder, two CRTs and a modem
Ajisai flash timing recorder	
Detection	rise/fall time measurements by using a PMT
Meteorological sensors	
Functions	temperature, humidity, pressure wind speed and wind direction
Shelters	
Size	2.1 m x 2.3 m x 3.5 m and 2.1 m x 2.3 m x 3.8 m
Weight	5 tons for two shelters including contents
Air condition	two air conditioners for cooling and heating
Power generator	
Output power	20 kW for AC 200 V and 7.5 kW for AC 100 V
Oil consuming	9 liters per hour for two generators

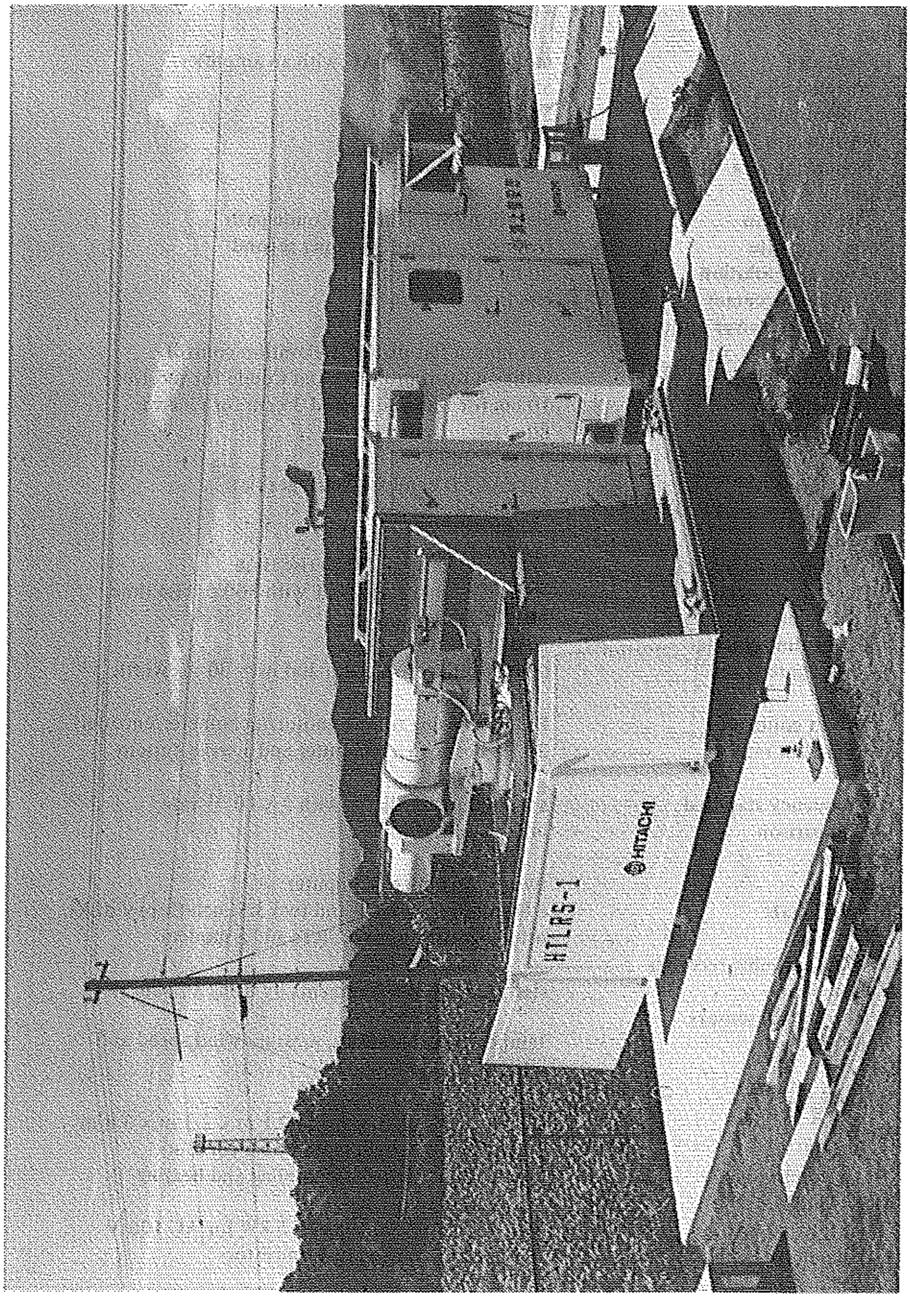

Figure 1. Overview of the Hydrographic Department Transportable Laser Ranging Station (HTLRS)

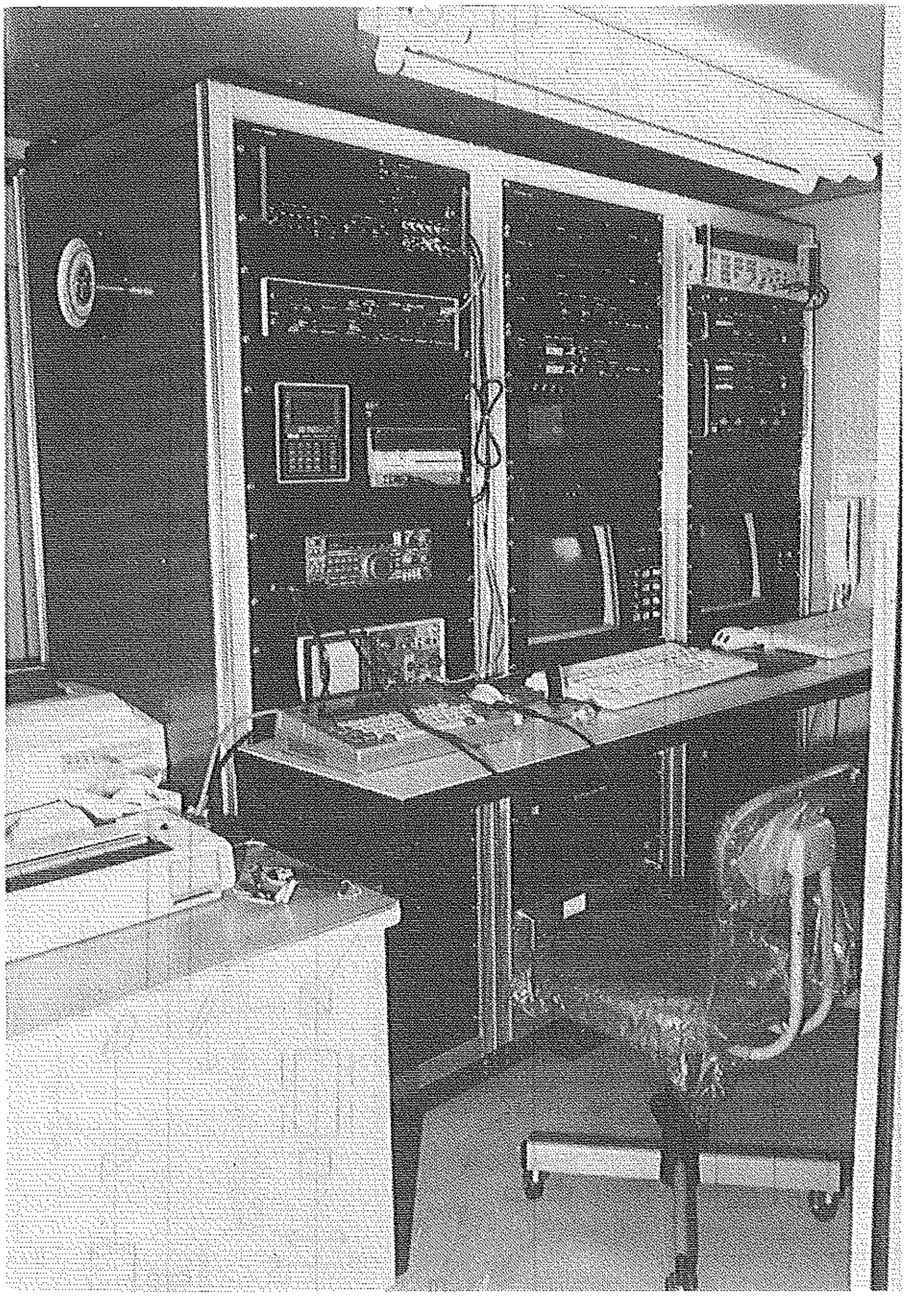

Figure 2. Control-, computer and clock subsystems of HTLRS

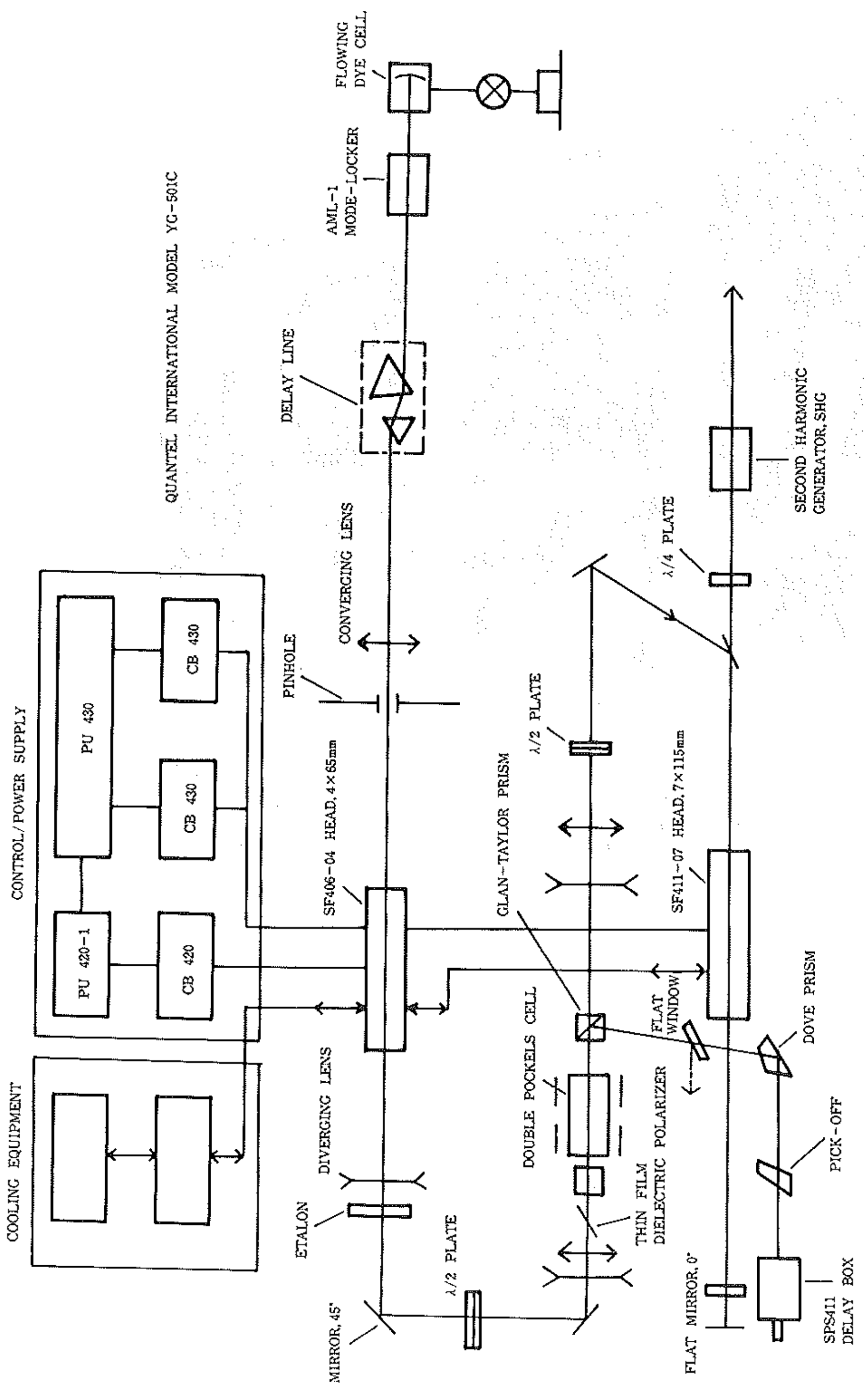

Figure 3. Optical block diagram of laser transmitter

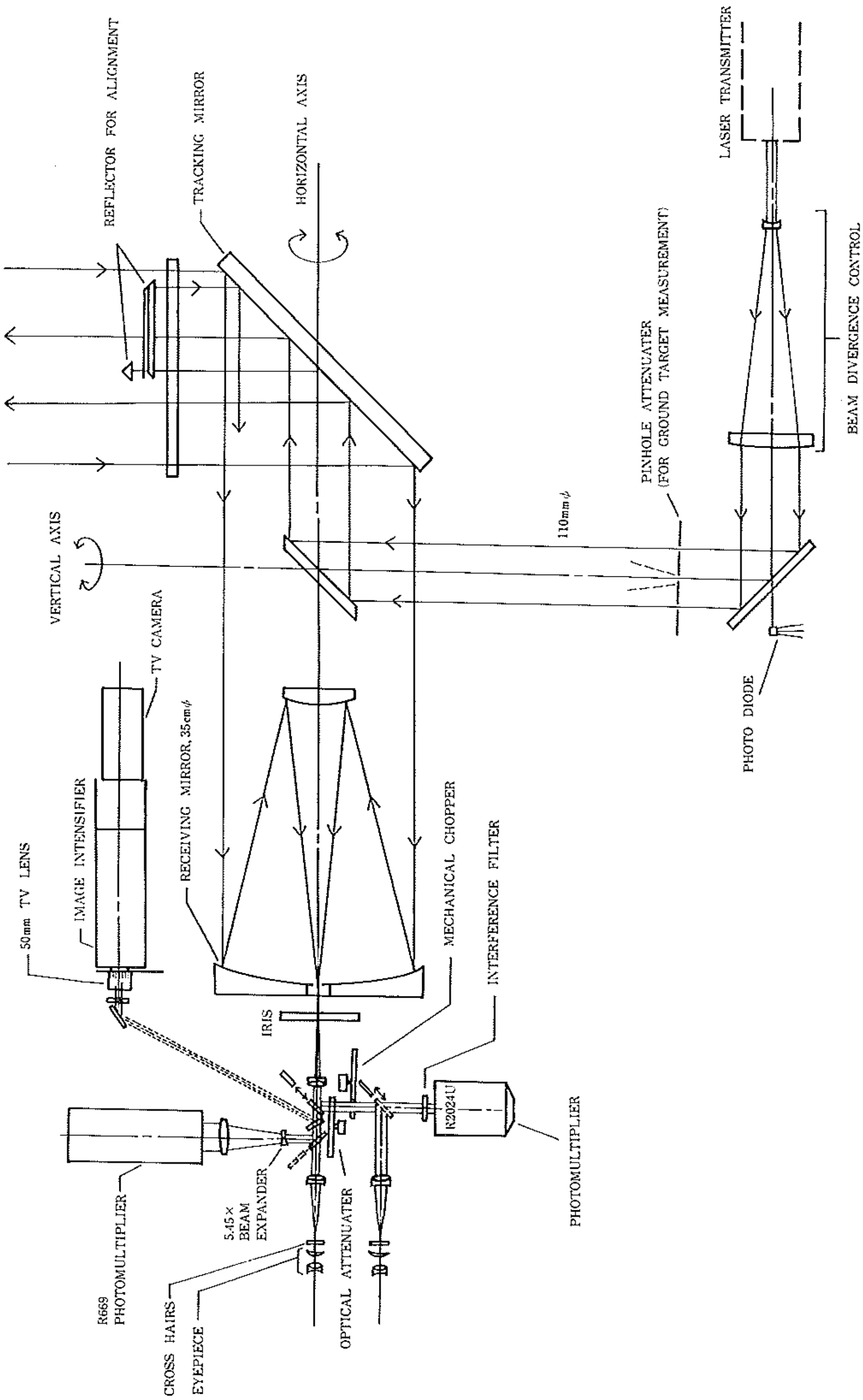

Figure 4. Block diagram of transmitting and receiving optics

測地衛星「あじさい」軌道予報システムの開発

DEVELOPMENT OF ORBIT PREDICTION SYSTEM FOR GEODETIC SATELLITE AJISAI

Satellite Geodesy Office has developed on orbit prediction system for Ajisai by combining the computer programs of data handling, orbit prediction computation, precision evaluation etc. so far developed at the Office.

Key words : orbit prediction － Ajisai

測地衛星「あじさい」の打ち上げに先立ち，衛星測地室では昭和60年度より人工衛星の軌道予報プログラム(SOAP, SAO 要素決定プログラム)，データハンドラ，検査プログラム等の開発を行ってきた。昭和61年度には，これら諸プログラムの精度を向上させるとともに全体を結合させて，「あじさい」軌道予報システムを開発した。衛星測地室では，このシステムを用いて昭和61年11月より「あじさい」の軌道予報を行っている。

1．全体構成

測地衛星「あじさい」は世界中のレーザー測距局で観測され，その日のうちに速報データが主としてテレックス回線を用いて NASA に集められている。水路部では，この速報データをあじさい観測データ通信網(G. E. Mark III) により週1回入手しており（仙石，1987)，この速報データから測地衛星「あじさい」軌道予報システムを用いて軌道予報を作成し，再びあじさい観測データ通信網（PC-Van, G. E. Mark III）により各観測所に送付している。

システムの全体構成を図1に示す。作業の流れは，以下の通りである。

1）送付されてきた速報生データを検査後フォーマット変換して，各プログラム用データファイルに変換する。(データハンドラ)

2）このデータファイルを用いて，あじさいの初期値，JHD 要素，SAO 要素等を決定する。
(SOAP, SAO 要素決定プログラム)

3）チェックサム等を加え，送付する形式に変換する。

本システムは，大型計算機(ACOS650)，ミニコンピューター(3B2)及びパーソナルコンピューター(PC9801)を有機的に連結させている。計算時間を要する本計算の部分(SOAP)は大型計算機で，データハンドラ，SAO 要素決定プログラムはミニコンピューターで，そしてデータの入出力はパーソナルコンピューターでと，各コンピューターの特長が最も発揮されるように配慮されている。

大型計算機と他のコンピューターとの間はフロッピィーディスクにより，また，ミニコンピューターとパーソナルコンピューターとの間は RS232C ケーブルによりデータのやり取りを行っている。

各プログラムは，Fortran, C, awk 等で書かれている。

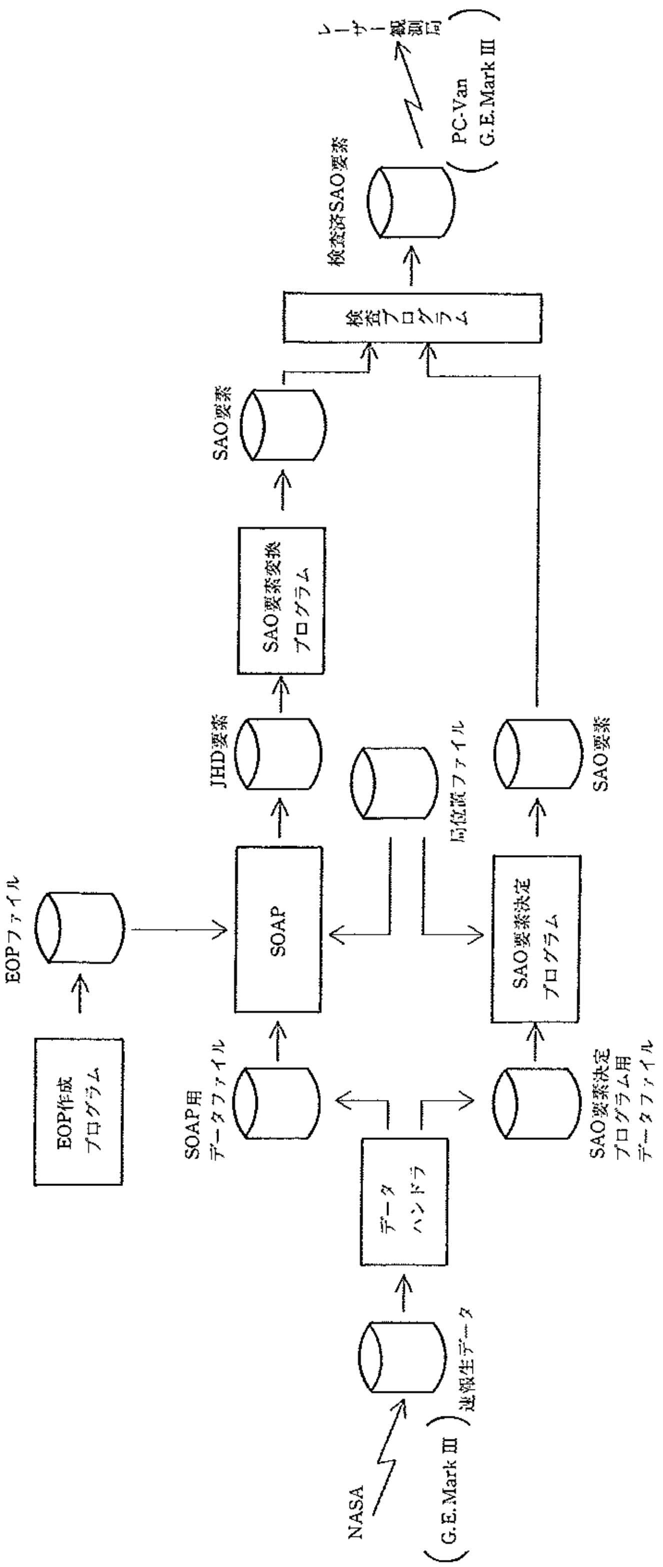

図1 「あじさい」軌道予報システムの概要

2．SOAP

SOAP（Satellite Orbit Analyzer Predictor）は，レーザー測距データ及び写真観測データから人工衛星の軌道を決定するプログラムであり，衛星測地室で開発された言語で記述されている（福島，1986）。これをFortranプリプロセッサにかけFortranソースに変換した後，コンパイルして実行している。この言語は，マクロ定義，include文等を使えるため，デバッグが容易でパラメーターの変更等も簡単に行える。

SOAPは，1987年8月現在第3版（SOAP III）が稼動している。これは，計9個のJHD要素（福島・仙石，1986）を最小自乗法により決定するものである。JHD要素は，以下の通りである。

n ：平均運動

ξ_0 ：$(e\cos\omega)_0$，但しeは離心率，ωは近地点引数，添字"$_0$"は元期での値を表す。

η_0 ：$(e\sin\omega)_0$

i ：軌道傾斜角

Ω ：昇交点経度

χ_0 ：$(l+\omega)_0$，但しlは平均近点角

$d\omega/dt$

$d\Omega/dt$

$\Delta(e\sin\omega)_0$

JHD要素は，測地衛星等円軌道に非常に近い人工衛星の軌道改良に有効な変数セットである。

SOAP IIIでは，J_2による短周期摂動の影響を解析的に加えている。

SOAP IIIによる予報の精度を図2に示す。図から明らかなようにレーザー測距に十分な精度を持っている。

現在，数値積分により衛星の初期値の推定を行うようにSOAPを改良中である（SOAP IV）。

3．SAO要素決定プログラム

SAO要素決定プログラムは，レーザー測距データ（または衛星の暦データ）からSAO要素を作成するプログラムであり，SOAPの検査用に作られた。現在SOAP IIIとほぼ同等の性能を持っている。言語は，Fortranを用いている。

SOAP IVが完成すると，SOAPとSAO要素決定プログラムは，直列につながれ1つのシステムに統合される（図3）。

4．データハンドラ

NASAから送られてくる速報データは，SAO形式とGLTN形式があり（Schutz, 1983），さらに大気補正の有無，内部遅延量の補正等に微妙な相違があるため，これらを統一したデータファイルに変換する必要がある。このために，データハンドラは以下の機能を持つ。

1）生のデータファイルよりデータの部分のみをとりだす。

2）データの検査を行う。

3）水路部の標準形式へとフォーマット変換を行う。

4）必要な諸補正を行う。

5）日別にファイル化し，統計処理を行う。

これらは，UNIXのシェル言語で書かれており，C, awk, Fortran等が用いられている。レーザーの速報デ

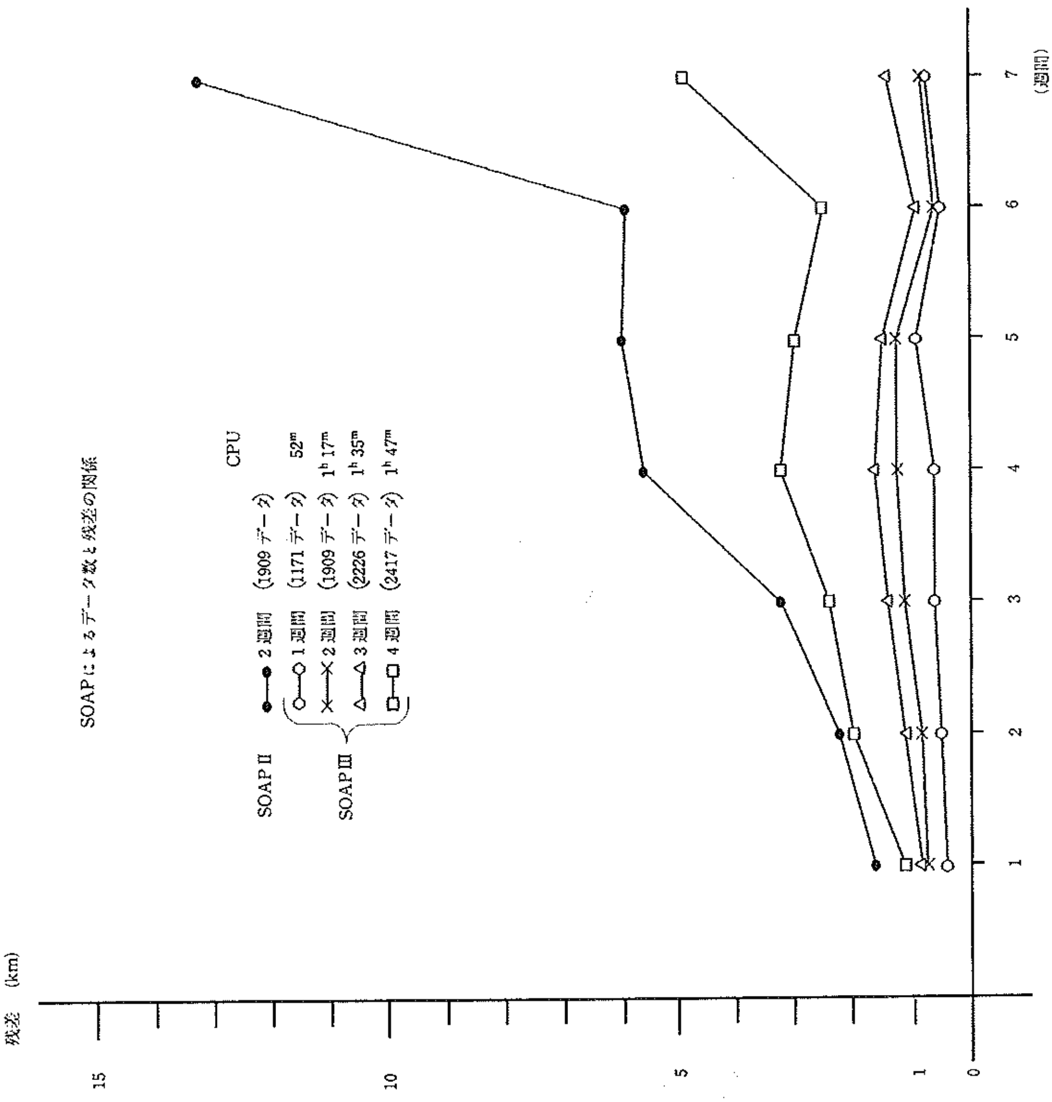

図2 SOAPによる予報の精度

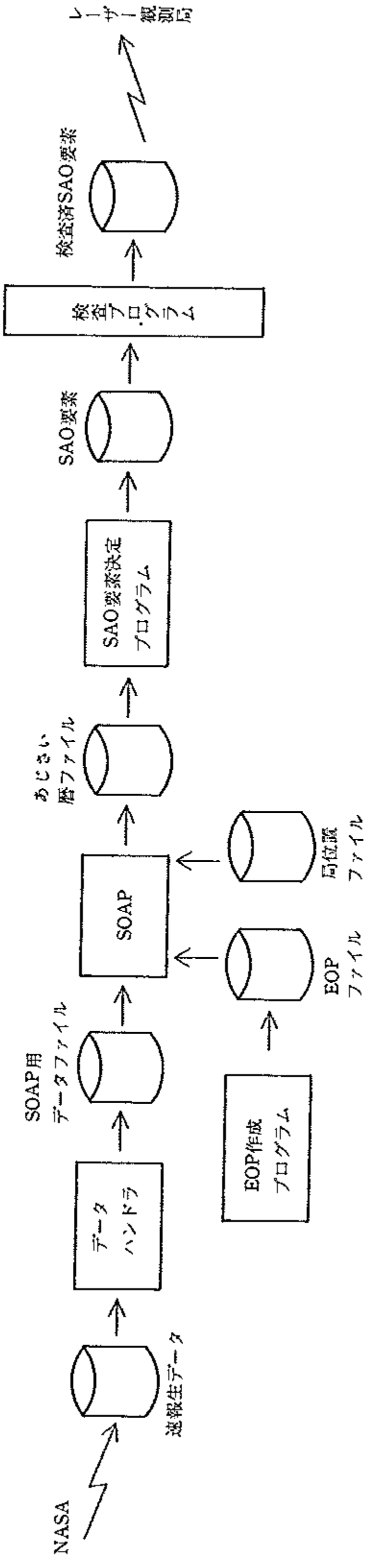

図3 「あじさい」軌道予報システムの将来像

ータのデータ量は10k バイト／週程度であり，ミニコンピューターの UNIX 環境はこの処理に最適であり，複雑な操作をほとんど無人で行える。

5．検査プログラム

作成した SAO 要素の精度を確認するために，軌道改良に用いた期間以前のデータを用いて検査を行う（改良に用いた期間以後も同様の結果になるものと考えられる）。衛星の軌道は SAO 要素から求めた平均軌道要素に J_2 による短周期摂動を解析的に加えて求めている。

検査によってレーザー測距に十分な精度と確認された場合は，この要素がレーザー測距局に送付される。

6．その他の雑プログラム

この他に，

1）JHD 要素―SAO 要素変換プログラム

2）SOAP 用 EOP（Earth Orientation Parameter）ファイル作成プログラム

3）予報送付時のチェックサム生成プログラム

等の諸プログラムがある。

7．今後の改良点

水路部の軌道予報の精度を向上させるために，今後以下のような改良を行う予定である。

1）SOAP Ⅳを完成させあじさいの初期値を精度良く予報できるようにする。

2）SAO 要素決定プログラム及び検査プログラムで，SAO 要素から衛星の位置を求める際のアルゴリズムを下里水路観測所のものと合わせる。

また，昭和63年１月に衛星データ整約装置が導入されれば，SOAP を大型計算機から衛星データ整約装置上へ移植する予定で，これによりファイル変換の手間が省け，UNIX 上でほとんどの処理を行えるため，作業効率をさらに向上できる見込みである。

「あじさい」軌道予報システムのうち，SOAP は福島登志夫，仙石新，長岡継，加藤剛が，SAO 要素決定プログラムは仙石新が，データハンドラは淵田晃一，福島登志夫，仙石新が，検査プログラムは仙石新が各々担当した。

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海図等に記載する測地系変換補正量の計算方法

CALCULATION FORMULA FOR THE RELATIONSHIP BETWEEN WGS-84 AND TOKYO DATUM INDICATED ON JAPANESE CHARTS

It is recommended by the International Hydrographic Organization (IHO) that all charts at scales larger than 1:500,000 shall carry appropriate transformation notes to enable the navigator to use directly or to convert to chart datum and vice-versa satellite-derived geographical positions which are in the worldwide datum. The Hydrographic Department indicates the transformation notes to convert the positions which are given in WGS-84 to chart datum, that is, the Tokyo Datum on the new charts since April, 1987. The notes will also appear on other charts in due course. Calculation formula for this conversion are reported in this article.

Key words : Datum conversion-Tokyo Datum-WGS84

水路部では，国際水路機関の海図仕様基準の勧告に基づき，縮尺 1/50万より大縮尺の日本測地系の海図及び海の基本図に，世界測地系に準拠する衛星航法システム，またはその他のシステムで得た経緯度を直接使用できるように，日本測地系と世界測地系の差を記載することとし，昭和62年 4 月刊行の図から記載しているほか，その他の海図等についても順次記載を行っている。その計算方法について報告する。

1．日本測地系と世界測地系

測地学で，地球の形を表現する場合には，回転楕円体が用いられる。楕円体の中心を地球の重心に置き，短軸を極の方向にとることを条件にして，地球の形に最も良く一致する楕円体を考え，経度の原点を定義によって定めれば，地球上の任意の地点の位置を経緯度と高さで表すことのできる座標系ができあがる。このように，回転楕円体の大きさや形だけでなく，地球との位置関係が具体的に定義され，任意の点の位置を数値で表現することの可能な座標系を測地系と呼び，実際に地球全体を対象とする測地系を汎世界的測地系と呼ぶ。測地系に用いられる回転楕円体を地球に対する位置関係まで含めて準拠楕円体と呼ぶ。

測地学で扱う地球の形とは，山や谷のある地表面のことではなく，重力の等ポテンシャル面の一つで平均海面に一致する面のことで，ジオイドと呼ばれる。ジオイド面は複雑な形をしており，これに全体として最も良く一致するような回転楕円体を求めることが，測地学の基本的な課題の一つである。

人工衛星の出現以後，汎世界的測地系に関する研究が急速に進み，汎世界的測地系として採用すべき座標系について，多くの研究者によって種々の数値が発表されている。なお，衛星航法等で用いられている WGS-72（World Geodetic System 1972）や WGS-84は，世界測地系と訳されているが，これらも数多く発表された汎世界的測地系の一つである。

汎世界的な測地系が実現されるようになったのは，人工衛星の出現以後のことであり，世界の各地で地図作成のための測量が盛んに行われるようになった19世紀の半ばには，地上の測量によって測ることのできる程度の範囲だけで一つの座標系が作りあげられ，遠く離れた地域では全く独立に座標系が作られた。たとえば，日

本の場合には，回転楕円体としてベッセル楕円体が採用され，天体観測の結果に基づいて東京の麻布に経緯度の原点が，また，高さの基準には東京湾の平均海面に基づく永田町の水準原点が決められ，経緯度原点から見た千葉県の鹿野山一等三角点の方向が天体観測から決められた。明治以後，日本の地図や海図は，この日本測地系と呼ばれる座標系によって作られてきている。しかし，今では日本測地系は汎世界的な測地系に対して数百メートル以上のずれがあることが明らかとなっている。

2．国際水路機関の勧告

世界の各々の地域あるいは国毎に異なった座標系が採用されて地図や海図が作成されてきたため，それらは互いに一致せず，また，最近普及している衛星航法等のシステムによって求められる座標値とも一致しない。衛星航法等のシステムの測位精度が向上するのに伴い，このような差異が無視できなくなったため，国際水路機関（IHO）は，各国の刊行する海図に自国の採用している測地系と衛星航法システムの測地系（具体的にはWGS-72もしくはWGS-84）との関係を示す数値を記入するように勧告した（IHO, 1984, 1986）。この勧告に従い，我が国も昭和62年4月刊行の海図からWGS-84と日本測地系との経緯度の変換量を記載しているほか，その他の海図等についても順次記載を行っている。

その文言は，次のようなものである。（記載例　海図第1247号A）

注意　世界測地系（WGS-84）に準拠する衛星航法またはその他のシステムで得た位置を本図に合わせるには，南へ0'.20，東へ0'.15移動しなければならない。

世界測地系（WGS-84）に準拠する衛星航法には，GPS（全世界測位システム）が該当する。NNSS（米海軍航行衛星システム）やロランC，オメガは，WGS-72に依っているが，WGS-72とWGS-84の差は高々20mの程度であり，より高精度の見込まれるGPSが準拠するWGS-84との関係を記述しておけば，WGS-72に準拠するシステムに対しても実用上差し支えがない。記載例にその他のシステムという表現を含んでいるのはこのような意味からである。

3．座標系の変換式

二つの測地系が与えられると，同一の地点に対する各々の測地系での経緯度，高さの間には，次のような数学的な関係がある。ここで数学的と書いたのは，測地系に歪みがないとした場合のことである。実際に三角点等の標石とその経緯度表で具体的に与えられる現実の測地系では，測量の誤差や計算方法の関係から，一般的には原点から離れるに従って本来あるべき数値からずれてくる。これを測地系の歪みと呼ぶと，日本測地系の場合には北海道や沖縄方面では10m程度の歪みがあることがわかっている。この歪みの問題については，第5節で取り扱い，ここでは歪みのない測地系を考える。

第1の測地系と第2の測地系を，1と2の添え字で区別する。準拠楕円体の長半径をa，偏平率をfとし，準拠楕円体の中心に原点を持ち，短軸方向（北向き）をW軸，それと垂直な面内で経度0°の方向にU軸，90°の方向をV軸とした直交座標系を考える。ある点の緯度，経度，高さ（楕円体高）を各々ϕ，λ，hとすると，その点の直交座標系での値は，

$$U_1 = (N_1 + h_1)\cos\phi_1\cos\lambda_1$$
$$V_1 = (N_1 + h_1)\cos\phi_1\sin\lambda_1$$
$$W_1 = (n_1 + h_1)\sin\phi_1 \qquad (1)$$

ただし，

$N_1 = a/(1 - e^2 \sin^2 \phi_1)^{1/2}$

$n_1 = N_1 (1 - e^2)$

$e^2 = f(2 - f)$

で表される。なお，楕円体高は，標高にジオイド高を加えることによって得られるが，ジオイド高は場所によって違うことに注意しなければならない。

ここで，異なる測地系に対しても各座標軸の向きは平行であると仮定する。この仮定は厳密には成り立たないが，ここでの作業にはこれで十分である。そうすると，二つの直交座標系の座標値の間の関係は，座標系の中心の平行移動で与えられる。この移動量を $\Delta U, \Delta V, \Delta W$ とすると，

$U_2 = U_1 + \Delta U$

$V^2 = V_1 + \Delta V$

$W_2 = W_1 + \Delta W$ (2)

と書ける。

直交座標系の数値を経緯度，高さ（楕円体高）に直すには，次のように繰り返し計算を行い，計算結果が収束するまで行う。

$\lambda_2 = \arctan (V_2/U_2)$

$R = (U_2^2 + V_2^2)^{1/2}$ (3)

このあと，繰り返し計算を行う。

$S_k = W_2 - e^2 m_k \sin \alpha_k$

$\alpha_{k+1} = \arctan(S_k/R(1-e^2))$

$T_{k+1} = a/(1-e^2 \sin^2 \alpha_{k+1})^{1/2}$

$m_{k+1} = (R/\cos \alpha_{k+1}) - T_{k+1}$ (4)

ただし，

$k = 0, 1, 2, \cdots\cdots$

$m_0 = 0$

$\alpha_0 = 0$

ここで，もし $|m_{k+1} - m_k| > m_o$ なら，k を1増して(4)式へ戻る。

ただし，$m_o = 0.001$m とする。

$|m_{k+1} - m_k| \leqq m_o$ なら，

$\phi_2 = \alpha_{k+1}$

$h_2 = m_{k+1}$ (5)

とする。地球半径にくらべれば高さ h は小さい量であるから，(4)式の計算はきわめて急速に収束し，3回程度でミリの桁まで収束する。

準拠楕円体の差による補正量を $\Delta\phi_T$，$\Delta\lambda_T$とすると，このようにして得られる ϕ_2，λ_2 ともとの ϕ_1，λ_1 との差が $\Delta\phi_T$，$\Delta\lambda_T$にあたるわけである。

$\Delta\phi_T = \phi_2 - \phi_1$

$\Delta\lambda_T = \lambda_2 - \lambda_1$ (6)

この補正は，地表での位置を500m 近く変えることになるので，陸地の近くではレーダーの映像等との比較によって，はっきり認識できる量である。

この量は場所によって異なるので，各海図に対して図の中心点での値を計算して用いているが，その変化の様子は緩やかであるので図の周辺部でもその差は問題とするほどではない。たとえば，WGS-84の経緯度を日本測地系に直す場合，東京では緯度で−0.″20，経度で0.″19の補正を行うが，青森でも各々−0.″16，0.″21と変わる程度である。

なお，計算手順の中で用いる高さは楕円体高である。一方，日常使う高さは平均海面から測った標高で，これを楕円体高にするためには，平均海面，すなわちジオイドの楕円体からの高さ（これをジオイド高と呼ぶ）を加える必要がある。ジオイドは唯一つしかないが，楕円体の方は準拠楕円体毎に異なるので，ジオイド高も楕円体毎に異なる。そこで，WGS-84ならWGS-84の，日本測地系なら日本測地系のジオイド高が分かっていなければならない。これまでの研究により，汎世界的な測地系に対するジオイド及び日本測地系に対するジオイドについて多くのモデルが発表されているので，それらを参照して各地点のジオイド高を求めることができる。ただし，海図に記載する変換量の場合には，話が経緯度すなわち水平方向だけに限られているので，出発点として与える高さはゼロとしてよい。出発点の高さの違いが座標系の変換後の水平位置に与える影響は極めて小さいのでここでは無視できるのである。

4．変換な必要な定数

世界測地系(WGS-84)と日本測地系の間で実際に経緯度の変換量を計算するには，各々の回転楕円体の諸元とともに，座標系の中心の平行移動量 ΔU，ΔV，ΔW が知られていなければならない。海図にこの測地系変換の補正量を記載するために航法測地課衛星測地室で採用している数値を第1表に掲げる。

Table 1. Parameters adopted to calculate the transformations of the positions from WGS-84 to Tokto Datum for Japanese nautical charts

世界測地系（WGS-84）	日本測地系（Tokyo Datum）	$\Delta U = U_2 - U_1 = +146.3$m
$a_1 = 6378137$m	$a_2 = 6377397.155$m	$\Delta V = V_2 - V_1 = -507.1$m
$f_1 = 1/298.257$	$f_2 = 1/299.152813$	$\Delta W = W_2 - W_1 = -681.0$m

a_2 と f_2 は日本測地系が採用しているベッセル楕円体の定義値で，a_1 と f_1 は WGS-84の準拠楕円体のものであるが，f_1 は米国防地図局の採用値である1/298.257223563を近似したものである。この f_1 の採用値の違いによって生じる差はきわめて小さく，厳密な議論の必要な場合以外では無視できる。米国防地図局が細かい端数を採用しているのは，地球の重力ポテンシャルの第（2，0）項を定義値とし，これをもとに偏平率を誘導定数として算出しているためである。

座標系の中心の平行移動量 ΔU，ΔV，ΔW を求めるには，同一の地点について各々の座標系の経緯度，楕円体高がわかれば良い。そうすると，(1)式によって U_1，V_1，W_1 と U_2，V_2，W_2 が共に得られるので，ΔU，ΔV，ΔW が計算できる。第1表に掲げた値は，第五管区海上保安本部下里水路観測所で1982年から実施されている人工衛星レーザー測距の暫定的な解析結果 (Sasaki, 1984) を用い，WGS-84と日本測地系の関係を推定したものである。人工衛星レーザー測距の解析に用いた座標系と WGS-84の座標系とは本来独立なものであるから，これらの座標系がどの程度一致しているかは検討を必要とする。WGS-84の座標系に関しては最終的な報告書がまだ発表されていないので十分にはわかっていないし，人工衛星レーザー測距の解析結果もデータの蓄積にともなって将来改訂されるであろうが，これまでに得られたデータから考えて両者の食い違いは，10m 程度以

内であると予想されるので，当面はWGS-84に対する定数を，この人工衛星レーザー測距の解析によって得られたものと同じと仮定して計算を行う。従って，これらの定数は，今後WGS-84に関するより正確な数値が得られた時には改訂していく予定であるが，その影響は小さいと思われる。

また，WGS-72とWGS-84の関係についても，現時点ではまだ断片的な情報しかないが，両者の最も大きな違いは経度の原点の約0″5の回転と伝えられるので，その差は高々20mのものである。航法用としてのNNSSやロランCの測位誤差は通常100m以上であって，これらのWGS-72に基づく測位結果を日本測地系に変換するのにWGS-84に対する値を使用しても実用上の不都合はない。

5．日本測地系の歪み

実際に地図や海図を作成する時には，そこに描かれる地形は三角点等の標石に基づいて測量され，その標石に付与された経緯度，高さの数値を根拠としている。一方，その三角点の位置は，経緯度原点から出発して三角測量によって展開された三角網の構成要素として与えられる。このような測量及びそのデータ処理の過程で生じる誤差と，細長く伸びる日本列島の地形的な特徴が合わさって，北海道や沖縄のように日本測地系の原点から最も遠い地域では誤差が大きくなっていることが予想される。近年，人工衛星を用いた精密な位置決定の手法が実現したことによって，このような日本測地系の内部の歪みが明らかになりつつある。その量は，地域によって10mを越えることもあるので，海図に記載する変換の補正量にはこれをわかっている範囲で取り込むことにした。その方法は以下のとおりである。

歪みのない三角網の経緯度を現実の三角点の経緯度に合わせるための補正量を $\Delta\phi_D$, $\Delta\lambda_D$ とし，以下のとおり定める。

(1) 北海道

$\Delta\phi_D = -0'.003$　　$\Delta\lambda_D = -0'.007$

(2) 東北地方（福島県を除く宮城，山形県以北）

$\Delta\phi_D = 0'$　　$\Delta\lambda_D = -0'.003$

(3) 中国，四国

$\Delta\phi_D = -0'.001$　　$\Delta\lambda_D = -0'.001$

(4) 九州北部（宮崎県，鹿児島県，対馬を除く）

$\Delta\phi_D = -0'.002$　　$\Delta\lambda_D = 0'$

(5) 対馬

$\Delta\phi_D = -0'.008$　　$\Delta\lambda_D = +0'.002$

(6) 宮崎県，鹿児島県（離島部を除く），甑島列島

$\Delta\phi_D = 0'$　　$\Delta\lambda_D = -0'.002$

(7) 南西諸島（三角網で日本測地系に結合されている地域のみ）

イ　北緯30°～31°

$\Delta\phi_D = +0'.001$　　$\Delta\lambda_D = -0'.002$

ロ　北緯29°～30°

$\Delta\phi_D = +0'.003$　　$\Delta\lambda_D = -0'.003$

ハ　北緯28°～29°

$\Delta\phi_D = +0'.004$　　$\Delta\lambda_D = -0'.003$

ニ　北緯27°～28°

$\Delta\phi_D = +0'.006$　　$\Delta\lambda_D = -0'.004$

ホ　北緯26°～27°

$\Delta\phi_D = +0'.007$　　$\Delta\lambda_D = -0'.004$

(8) その他

上記以外の地域は $\Delta\phi_D = 0'$, $\Delta\lambda_D = 0'$ とする。

なお，離島等について，上記条件に当てはまらないものは，航法測地課において個々に決定する。

ここで注意しておきたいのは，これらの補正量は，歪みのない完全な日本測地系での経緯度の値を現実に使われている歪みを持った日本測地系に合わせるための量であることである。なぜなら，地図や海図に描かれた地形は歪みを持った日本測地系に基づいているからである。航法測地課では，海洋測地の観測等を通じてこれまでに判明している日本測地系の歪みの量に基づいて，この補正量をブロック毎に一定であると仮定して北海道から九州までをいくつかのブロックに分けて数値をきめるとともに，南西諸島については，鹿児島と沖縄本島の間で歪みが直線的に変化するものと仮定して比例配分によって決めた。また，南西諸島の中でも宮古島以西の島々や南方諸島のように，もともと日本測地系に結ばれていない地域については，個々の島についてデータを当たって見ないと決められない。

これら $\Delta\phi_D$, $\Delta\lambda_D$ の量についても，今後データが蓄積され，より正確な数値が得られた時には改定して行く予定である。

6．まとめ

世界測地系(WGS-84)の経緯度を日本測地系の経緯度に変換するための補正量を求めるための手順は，第1表の数値を用いて(1)から(6)までの式によって $\Delta\phi_T$, $\Delta\lambda_T$ を求め，第5節の日本測地系の歪みの量 $\Delta\phi_D$, $\Delta\lambda_D$ を必要により加えることで与えられる。50万分の1よりも縮尺の大きな海図について，この方法によって計算した各海図の中心点の位置に対する補正量が記載されているが，その値は各図の中で一定と考えても航海に用いる範囲では差し支えない。

WGS-84に関してはまだ十分な情報が得られているわけではないが，海図に記載する最終桁である0'.01の程度の精度ではもはや大きくは違わないものと予想される。もし，変換量を上記の式によりこれより高い精度で計算しようとする場合には，WGS-84等に関する情報に注意し，諸定数に最新のものを用いる必要がある。また，測地学的な目的で厳密な計算を行う場合には，f_1 の端数やジオイド高についても考慮を払わなければならない。

本報告は，金沢輝雄が作成した。

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NOTE ON THE SATELLITE LASER RANGING OBSERVATION IN 1986

Summary – The efficiency of Satellite Laser Ranging (SLR) observations performed at the Simosato Hydrographic Observatory (SHO) is discussed. Some topics on the SLR system at the SHO are explained. The ranging characteristic of this system is discussed also.

Key words: satellite laser ranging – global geodesy

This paper gives complementary information to the paper titled "SATELLITE LASER RANGING OBSERVATIONS IN 1986" (Kanazawa, 1988) included in the same volume of this report. The emphasis is put on the technical side of the Satellite Laser Ranging (SLR) system at the Simosato Hydrographic Observatory (SHO).

1. Efficiency of observation

In order to study the efficiency of SLR system at the SHO, we present Tables 1 and 2 and Figures 1 and 2.

Table 1 shows the numbers of passes we tried and succeeded in SLR observation in 1986 for the satellites Lageos, Starlette, Beacon (BE)–C and Ajisai, respectively. The numbers of daytime passes are given in parentheses. The value for BE–C in 1986 is for the observations during January through June while that for Ajisai is for those since the launch of Ajisai in August, 1986. The detailed information on this change of observed satellites is written in Kubo (1988). The full information of observed passes is given in Kanazawa (1988).

The ratio of tried and observed passes is also listed in Table 1 year by year since the start of SLR observation at the SHO. It is remarkable that the ratio for Ajisai exceeds 90% even in daytime observation. This fact shows that the satellite Ajisai is much easier to be observed than Lageos.

Table 2 lists the total number of laser pulses we shot and received through the year 1986 for each satellite. The column for the ratio of returns and shots clearly presents the high efficiency of Ajisai as an SLR target. The comparison with the cases of Lageos and Starlette tells us that this high efficiency is achieved partly due to the relatively low altitude of Ajisai and partly due to a large number as well as a large effective area of the retroflectors equipped on the surface of Ajisai.

The averaged numbers of returns per pass are also shown for each year in Table 2. A relatively strong correlation between this and the year-by-year variation of successful passes in Table 1 indicates that a high efficiency in detection of return pulses improves the number of successful passes.

Figure 1 shows the number of laser pulse returns per pass for Lageos, Starlette and Ajisai. The bright area depicts the observations at daytime while the dark one does those at night.

Table 1. Numbers of Passes Tried and Observed

( ) Daytime

Satellite	Tried Passes in 1986	Observed Passes in 1986	Observed/Tried Ratio				
			1986	1985	1984	1983	1982
			%	%	%	%	%
LAGEOS	310 (103)	224 (35)	72 (34)	77 (57)	54 (34)	36 (22)	28 (18)
STARLETTE	109 (68)	92 (57)	84 (84)	82 (81)	64 (57)	54 (49)	42 (5)
BE–C	83 (49)	56 (31)	67 (63)	77 (74)	59 (56)	62 (50)	40 (32)
AJISAI	181 (76)	169 (73)	93 (96)	–	–	–	–

BE–C (in 1986): Jan. – Jun., AJISAI : Aug. – Dec.

Table 2. Numbers of Shots and Returns

Satellite	Returns in 1986	Shots in 1986	Return/ Shot	Averaged Returns per pass				
				1986	1985	1984	1983	1982
			%					
LAGEOS	147526	2389600	6.2	658	815	418	221	221
STARLETTE	25286	191800	13.2	275	359	320	268	94
BE–C	15359	126800	12.1	274	440	374	454	175
AJISAI	138956	497200	27.9	822	–	–	–	–

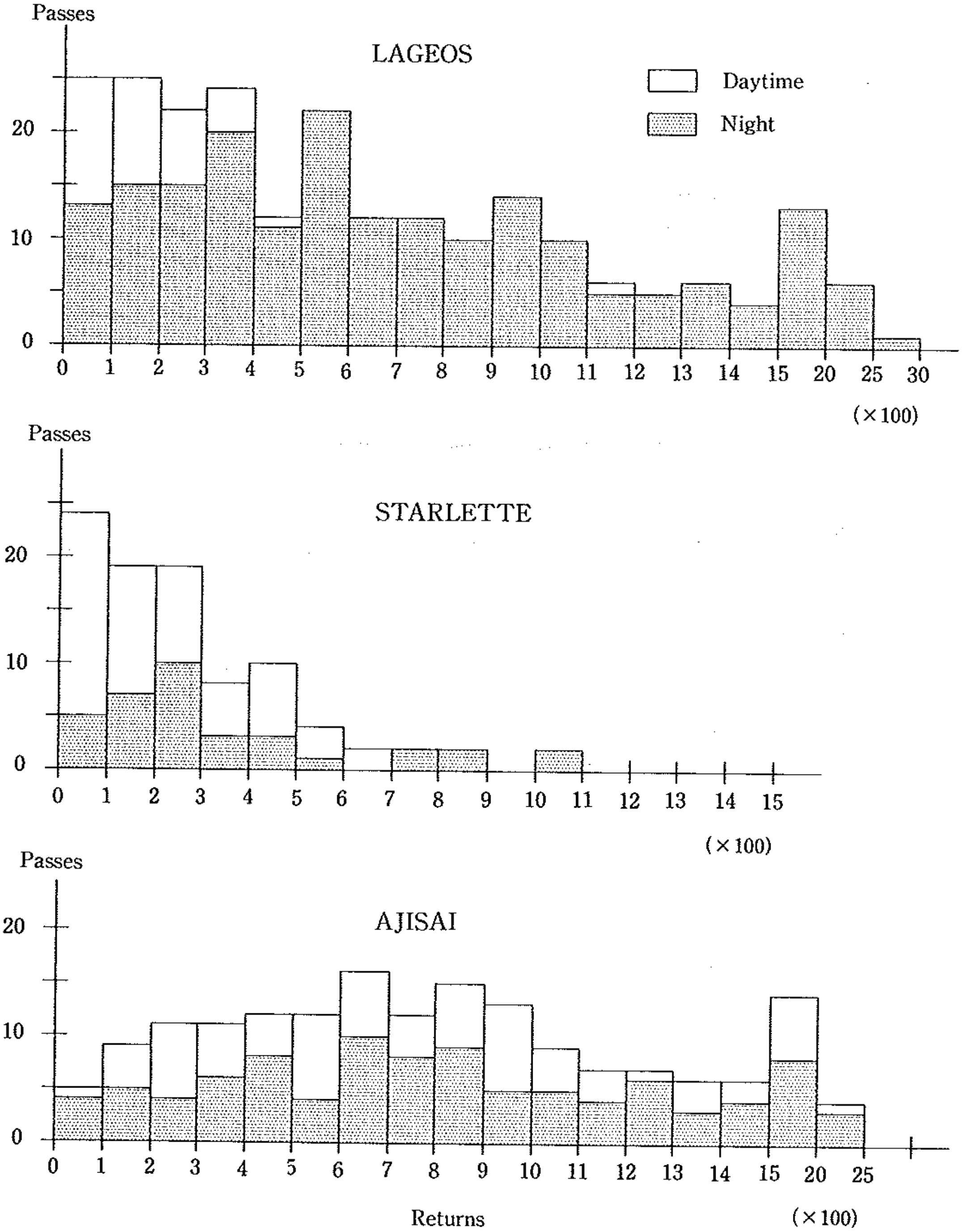

Figure 1. Number of returns per pass

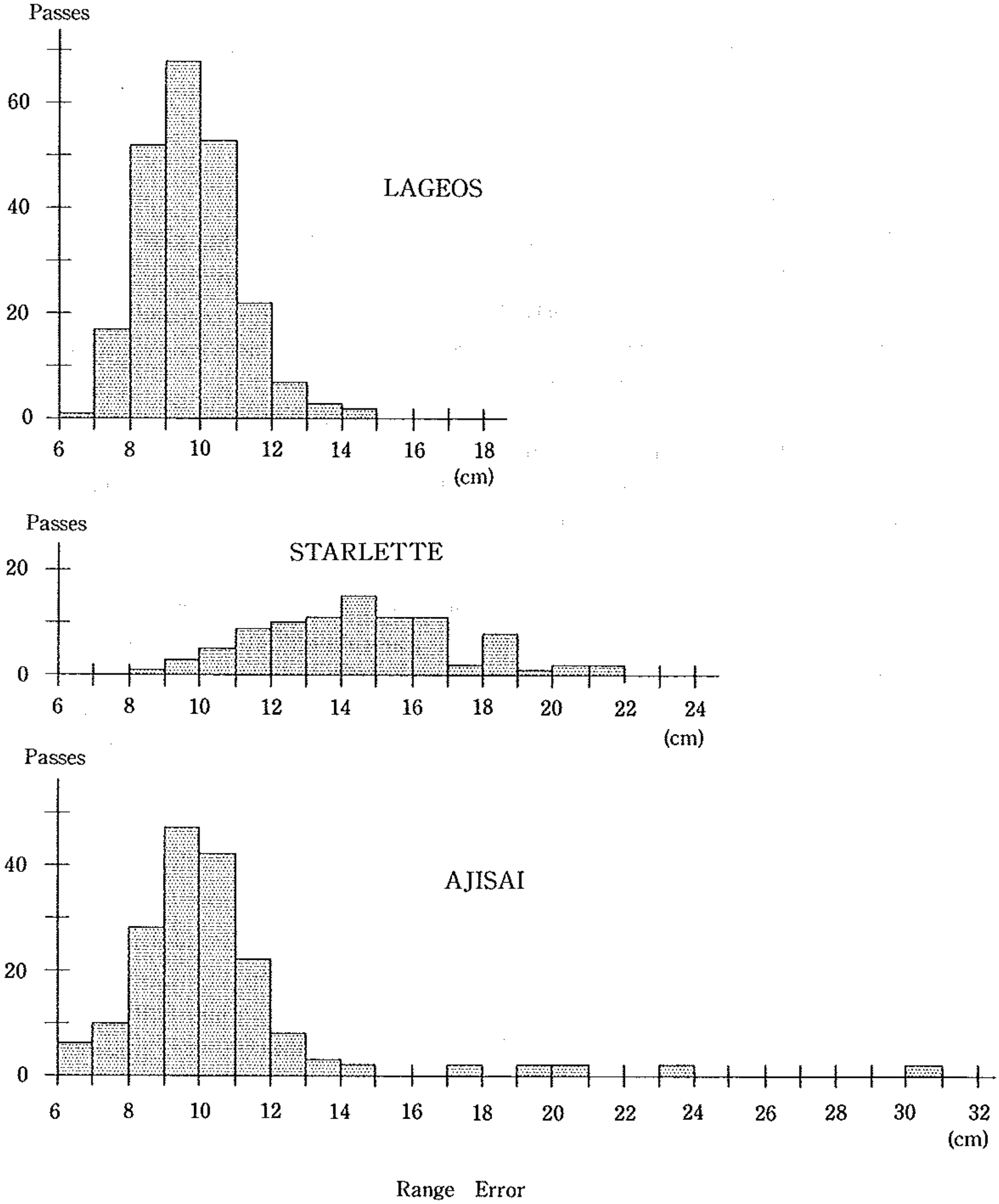

Figure 2. Distribution of range error

Figure 2 illustrates the distribution of ranging accuracy for Lageos, Starlette and Ajisai. Here the ranging accuracy means the standard deviation of residuals obtained by a 9-th order polynomial fitting to the raw data.

2. Topics on SLR system in 1986

2.1 Damage of Pockels Cells

We have been troubled with the optical damage of the Pockels cell No. 4 (PC4) since August, 1985. We replaced the PC4 in December 1985 and it was damaged immediately after the replacement. At present we make the power of the regenerative amplifier as small as possible in order not to increase the damaged area so much. This is not a good resolution because it makes the generation of laser pulse much unstable.

This damage seems to arise from the change of matching oil for the cell from FC104 to FC43 because the damage happened a little after the change. The former oil is now sold out and we can purchase only the latter. The optical characteristics of these two oils are almost the same, however, the viscosity is much different.

2.2 Photomultiplier

On March 27, 1986, we changed the photomultiplier from the MCP–PMT R2024U (No. 79) made by the Hamamatsu Photonics K.K. to a new one R2024U (No. 162) in order to remodel No. 79. The staff at the Hamamatsu Photonics K.K. tested the old one (No. 79) and assured its quality was almost the same as when it had been used at the SHO before. The remodeling of No. 79 was made so as to make the time constant of gate variable in the range of 5 s to 5 ms and to add a new gate pulse generator which enables us to change the gate pulse width as 5 s, 10 s, 20 s, 50 s, 100 s, 500 s, 1 ms and 5 ms. The remodeling finished in the middle of July and we started to use the remodeled No. 79 on July 18.

2.3 Improvement for Observing Ajisai

In order to observe the Ajisai which was launched on August 13, we added a remote control box with a joystick on May 23 and a wide-field finder telescope of the 14 cm diameter named SP–140SS on July 16. These enable us to control the whole SLR system while watching the reflection light of the satellite, which increased the observation efficiency for Ajisai drastically.

2.4 Trouble in Interference Filter

On December 4, 1986, when the maintenance staff from the Hitachi Ltd. researched the pattern of received laser pulse from Ajisai, the heater of the interference filter was damaged. This brought an instability into the temperature control of filter, which degraded the detection efficiency until December 15. On December 16, we adjusted the temperature to about 37°C which seemed to be optimal by a preliminary test. Since then the detection efficiency was recovered although the transparancy of filter decreased to 20%.

2.5 Clock Comparison by Transportation

During the 2nd and 5th of July, 1986, we made the comparison of atomic clocks between the SHO and the Tokyo Astronomical Observatory at Mitaka, Tokyo by transporting the SHO clock to Mitaka. However, our atomic clock suffered the variation of battery voltage or temperature during the transportation so that the rate of clock was not maintained so good. Therefore the result of comparison for this year is not reliable. Further investigations are needed to find a more accurate and reliable way of clock comparison.

3. Ranging characteristic of SLR system

We researched the ranging characteristics of our SLR system at the SHO by performing a ranging to ground targets with a variety of values of parameters.

At first, after warming up the regenerative amplifier about half an hour, we performed a continuous ranging to a ground target for more than two hours in the same way we observe the Lageos. Figure 3 shows the time variation of 10 minutes average of obtained ranges after the atomospheric correction. The data concerning the measurement are as follows:

Date of experiment	:	January 9, 1987, 1900-2200 JST
Highest voltage	:	2750 V
Start threshold level	:	60 mV
Stop threshold level	:	8 mV
Attenuater value	:	17 dB
Observer/Recorder	:	E. Nishimura and H. Sasaki

The surveyed value of baseline length is 1414.6987 m while the mean value of ranging was 1416.274 m with a standard deviation of 0.047 m. The time variation of 10 minutes average of ranging reaches to 4.2 cm for the maximum to minimum difference while the standard deviation is 0.9 cm. The stability of generating a laser light was not so good during this experiment.

Next, we made a ranging to a ground target varying the attenuater value from 24 dB to 4 dB. Figure 4 shows the obtained 1 minute average of ranging data. The data of measurement were the same as in the first experiment except for the attenuater value and the date of experiment which was January 20, 1987, 1900-1930 JST. We could not obtain a meaningful range for the attenuater value less than 12 dB, probably because the reflecting light was too strong. The arrow in the figure depicts the standard value for our SLR observation.

Thirdly, we did the experiment similar to the second one varying the stop threshold level from 32 mV to 2 mV. Figure 5 shows the obtained 1 minute average of ranging data. The data of measurement were the same as in the first experiment except for the stop threshold level and the date of experiment which was January 20, 1987, 1935-2005 JST. Just as the same as in Figure 4, the arrow in the figure depicts the standard value for our SLR observation.

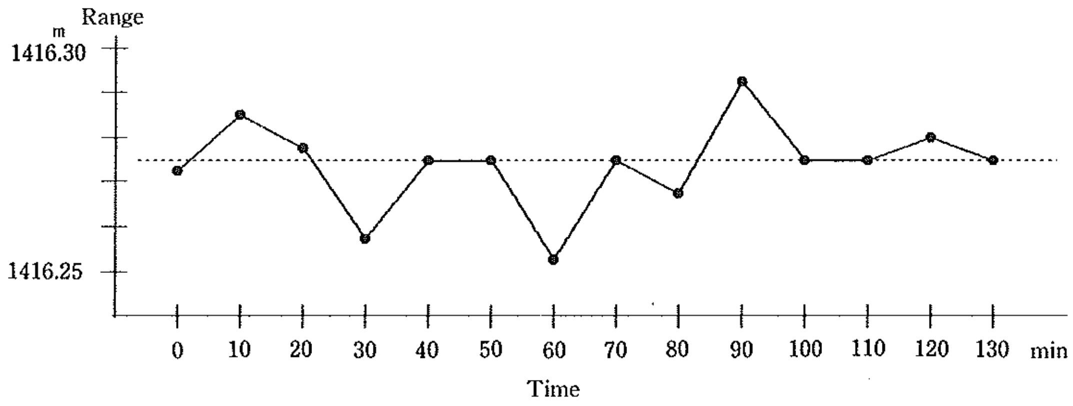

Figure 3. Time Variation of range to ground target

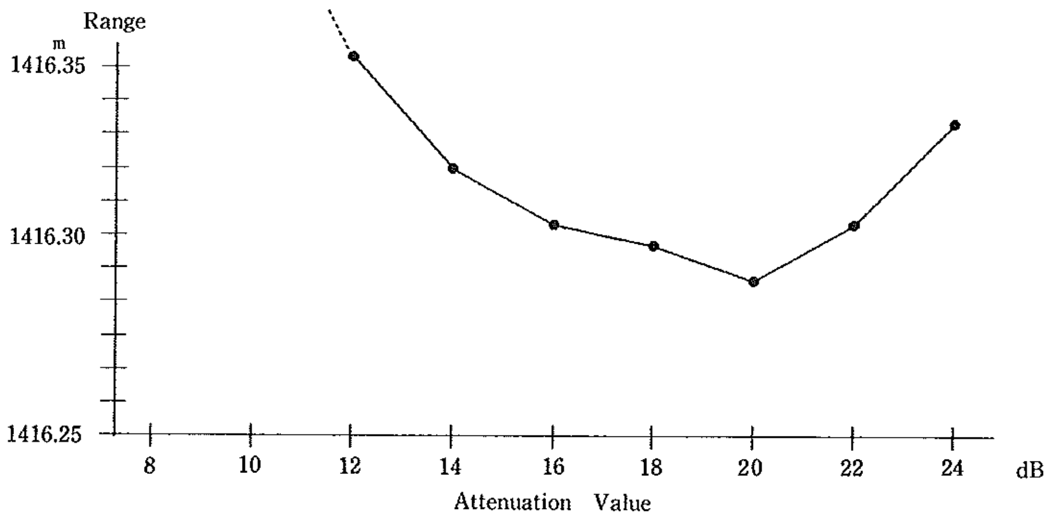

Figure 4. Attenuation value v.s. range to ground target

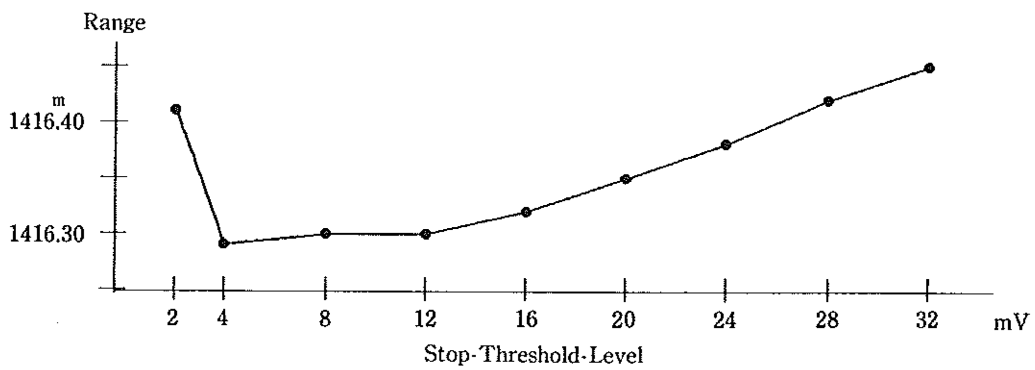

Figure 5. Stop-Threshold-Level v.s. range to ground target

Judging from the result of these experiments, we believe that the smaller the amplitude of return laser pulse is, the larger the obtained value of range becomes as long as the measurement environment is normal. However, the amplitude greater than the normal value seems to affect the voltage in the amplifier circuit so that the phase of measured signal or amplification factor of the circuit varies. This occurs probably because the dynamic range of amplifier used in the detection part of our SLR system is so narrow that the input signal with a large amplitude will be transformed into a strongly deformed output signal due to the saturation effect. This conjecture is partly supported by a kink in Figure 4.

This paper was written by T. Fukushima of the Satellite Geodesy Office on the basis of the report made by E. Nishimura of the SHO.

Reference

Kanazawa, T. 1988: *Data Report of Hydrogr. Obs., Series of Satellite Geodesy*, No. 1, P.76.

Kubo, Y. 1988: *Data Report of Hydrogr. Obs., Series of Satellite Geodesy*, No. 1, P.1.

「あじさい」の打ち上げ直後及びその後の観測状況

OBSERVATIONS OF AJISAI ON THE DAY OF ITS LAUNCH AND ON THE FOLLOWING DAYS

Observations of Japanese geodetic satellite Ajisai have been made at the Hydrographic Observatories, other institutes in Japan and many observatories in the world since immidiately after its launch to this day. This report reviews how those observations of Ajisai have been made, especially focusing those conducted immediately after the launch.

Key words : Ajisai-photographic observation-SLR

1．はじめに

わが国初の測地衛星は，1986年８月13日午前８時45分（日本時），宇宙開発事業団（NASDA）種子島宇宙センターより，同事業団により打ち上げられた。衛星は予定どおりの円軌道に投入され「あじさい」と命名された。

同衛星は，十数年前から水路部が国土地理院とともに，宇宙開発委員会に対して打ち上げを要望してきたものである。なおかつ，現時点においては水路部は，海洋測地網の整備における離島の位置決定という明確な利用計画を持つ唯一の機関である。従って，「あじさい」の実質的に唯一の利用者として水路部は「あじさい」打ち上げ直後の捕捉観測及び初期軌道の決定について重大な関心を持たないわけにはいかなかった。このため４つの水路観測所，すなわち八丈，白浜，下里，美星の各水路観測所を総動員して打ち上げ直後の観測に全力をあげることとした。特に下里水路観測所はレーザー測距（SLR）観測を経常的に実施し得るわが国で唯一の観測所であることから，初期軌道決定において同観測所の果たす役割に期待されるところは大きかった。

NASDA としても，打ち上げた衛星を見失うということは許されないので，国内の観測可能なあらゆる機関に依頼し，またアマチュア天文家を動員して，捕捉観測及び初期軌道決定のために万全の体制を敷いて待機した。

その他，外国の観測所，特に SLR の観測局の協力が不可欠であったが，これには水路部が米国航空宇宙局（NASA）を通じたり，あるいは直接通信によって観測の依頼をした。結果的には，多くの外国の観測局での SLR データが得られ，これが「あじさい」の初期軌道の決定に大きく貢献した。

本稿では，「あじさい」打ち上げ当日，及びその後における「あじさい」の観測状況について取りまとめを行う。なお，打ち上げの状況の詳細については水路要報第108号（昭和63年２月）１ページを見られたい。

2．水路部における観測

(1) 打ち上げ当日の観測

水路部では４水路観測所において，捕捉観測を行うべく観測体勢を整えて待機した。観測機器は次のとおりである。

① 写真観測（各水路観測所）

a）カメラ：

タカハシ製ε－160反射式天体カメラ（赤道儀架台付）にマミヤ製60㎜ロールフイルムホルダー（吸引式に改造）を装着

b）時刻測定装置

SEIKO「CT-816」（計測単位：1/1000秒）

c）使用フイルム

コダックローヤルXパン（現像は2倍増感を標準とした）

d）観測方法

観測方法については1986年6月17日～6月20日，各観測所から1名が本庁に集まり，観測法・記録法・整約法等の検討，機器操作の実習等を実施した。

撮影は赤道儀により，恒星を追尾しつつ行った。恒星と「あじさい」の点像との区別を容易にするため，恒星については衛星通過後，視野を少しずらして再度露出して二重像にすること等が当初検討されたが，その必要性はないことがわかった。結果として衛星の点列の並びは一目瞭然であり，恒星と衛星点像との区別はまったく問題がなかった。

発光の時刻の測定については，上に述べた計時装置に，望遠鏡で眼視で確認した衛星の発光に合わせて手で信号を送り，記録する方式が望ましいと思われたが，衛星の光が弱く，かつ点滅のスピードが速いため不可能とわかり，カメラのシャッターの開閉時刻から衛星像の点列の最初と最後のものの時刻を同定し，あとは比例配分するというような方式をとらざるを得なかった。光の点滅の間隔は約0.5秒なので，この方式での時刻測定の精度は0.5秒程度ということになる。

撮影したフイルムはSAO星図により恒星の同定を行い，恒星及び衛星各点像の座標を読み取り，衛星の点像の赤経・赤緯を計算することとされた。しかしながら，後述するように各国のSLR観測が早い時点から成功し，精度の良いデータが多量に得られたため，写真観測のデータは軌道の計算にほとんど利用されることがなかった。

各観測所での8月13日，つまり打ち上げ当日夜の観測の成否がどうであったかの状況は，表1に掲げる。図1.a～1.dに各観測所で撮影された「あじさい」の写真を掲載する。

② SLR観測

下里水路観測所において，昭和57年に設置された，いわゆる固定式人工衛星レーザー測距装置によって，打ち上げ当日から観測が行われた。

8月13日夜，日本で通過が観測できる最初のパス（第8周目），「あじさい」を確認できず，レーザーの発射に至らなかった。第9周目では「あじさい」を案内望遠鏡の中心にとらえレーザー光を発射したが，反射光をとらえることができなかった。第10周目は天候が悪く観測不可能であった。そして第11周目に初めて測距データが得られ，次の第12周目でも観測は成功した。

表1に，写真観測とあわせた，衛星打ち上げ当日の夜の各水路観測所における観測の成功・不成功の状況を掲げる。

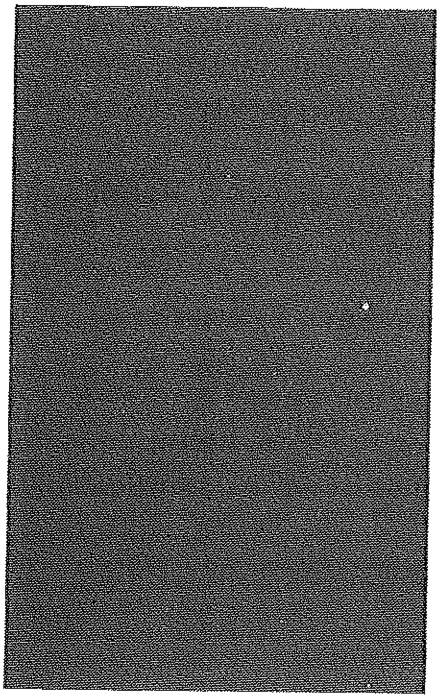

Figure 1.a. Hatizyō Hydrographic Observatory
1986.8.13 $22^h36^m43^s \sim 22^h37^m08^s$(JST)

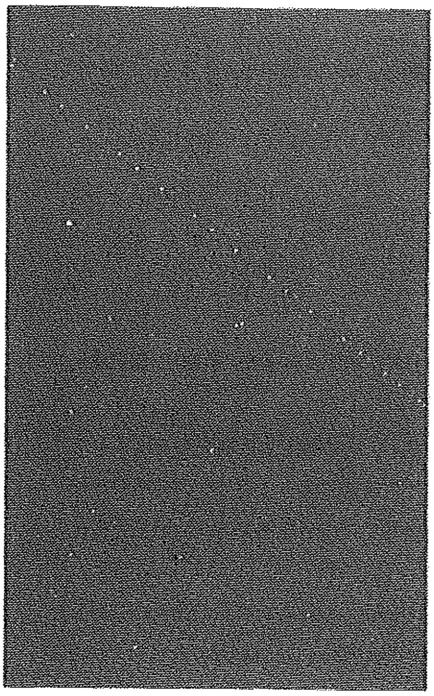

Figure 1.b. Shirahama Hydrographic Observatory
1986.8.14 $19^h44^m54^s \sim 19^h45^m10^s$(JST)

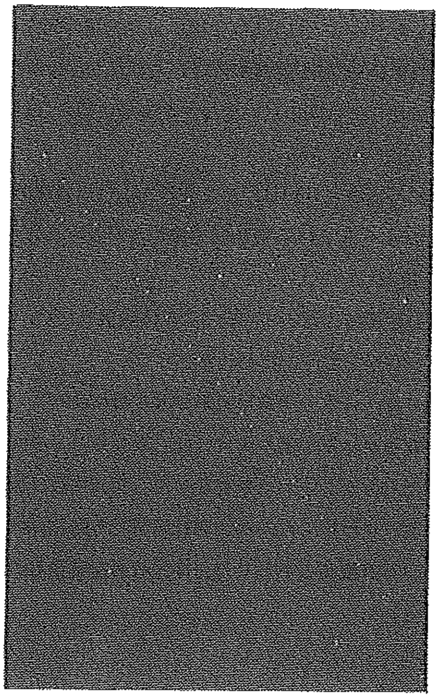

Figure 1.c. Shimosato Hydrographic Observatory
1986.8.14 $19^h46^m03^s \sim 19^h46^m16^s$(JST)

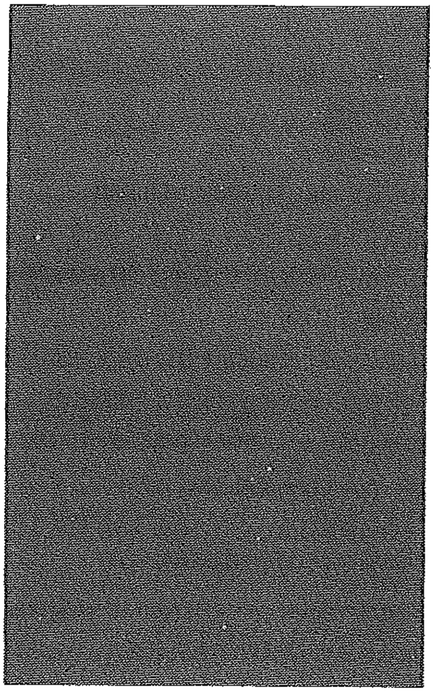

Figure 1.d. Bisei Hydrographic Observatory
1986.8.14 $0^h42^m50^s \sim 0^h42^m58^s$(JST)

Figure 1. Photographs of Ajisai taken at Hydrographic Observatories

Table 1. The result of observations of Ajisai made at the Hydrographic Observatories on the day of the launch

周回数		8	9	10	11	12
八丈水路観測所	写真	×	○	×	○	×
白浜水路観測所	写真	○	○	○	×	×
下里水路観測所	写真 レーザー	× ×	○ ×	× ×	× ○	× ○
美星水路観測所	写真	○	○	○	×	×

○：成功　×：不成功

Table 2. The monthly statistics of the SLR observations of Ajisai at the Simosato Hydrographic Observatory in 1986

年 月	パス数	リターン数
1986年 8月	27 (1)	25303 (536)
9	33 (22)	34807 (24386)
10	34 (22)	28383 (16468)
11	30 (4)	24271 (3644)
12	45 (24)	26192 (12818)
計	169 (73)	138956 (57852)

( ) 内は昼間観測数

(2) その後の観測

写真観測は８月14日以降も続けられたが，SLR 観測によるデータが十分に得られ，写真観測のデータは軌道計算には必要がなくなったため，８月23日で打ち切った。ただし，「あじさい」が見失われるか，軌道の決定精度が著しく低下した際にはいつでも再開することとされた。

下里水路観測所における SLR 観測は打ち上げ翌日以降休むことなく続けられ，今日に至っている。1986年における観測の月別のパス数及びリターン数は表２のとおりである。

３．国内他機関の補捉観測

国内では水路部，国土地理院はじめ表３に掲げる機関，及びアマチュア天文家の組織が NASDA に協力して打ち上げ直後の補捉観測に参加した。その成否の状況は表３に示すとおりであった。

これらの観測は数日で打ち切られたが，その後も下里水路観測所，国土地理院鹿野山測地観測所は３週間に１週を指定し，５パス程度の観測を行い，結果を NASDA に送付している。もっとも下里水路観測所については定常的に観測を行っているので，この指定には特に意味がない。

４．外国における SLR 観測状況

「あじさい」の SLR 観測は NASA をはじめとする世界の各局で精力的に行われている。打ち上げ当日も，日本で初めて観測が可能となる前に，既に多くの局で観測に成功した。

打ち上げ当日及び翌日の各国の観測状況を表４に示す。これは NASA から水路部に送られてきた MT によるフル・レートの観測データによって調査したものである。

表５には同じ調査による1986年における月別の外国各局の観測数（パス数）を掲げる。

５．データの収集，各観測局との通信，軌道予報の計算

国内の観測データは NASDA に集められ，NASDA は軌道の解析及び予報を行うこととされていた。実際にそれは実施され，現在も続いている。

一方，水路部には下里水路観測所のデータはもちろん，各国の SLR 観測のクイック・ルック・データが NASA を通じて送られてくる。これを用いて，水路部でも SLR 観測に必要な予報を計算することとしていた。打ち上げ直後はその予報プログラムは完成していなかったが，４月に SOAP III というプログラムが完成し，一応の予報が出来るようになった。しかし後述する NASA の予報の精度には少し及ばないようである。SOAP IIIは数値積分による SOAP IVにヴァージョン・アップすべく現在改良中であり，これが完成すれば NASA と同等の精度になると考えられる。

その他の各国ともデータ交換のチャンネルのあるところもあるが，予報計算に必要なクイック・ルック・データという形では現在は入手していない。

NASA には，従来からの NASA の主催する地殻力学プロジェクトを通じて，あらゆる衛星の SLR データが入る仕組みになっている。特に「あじさい」の打ち上げ以降，それまでの Beacon-C の予報をやめ「あじさい」の予報に切り換えることにしたので，各国で「あじさい」の観測を行うようになり，NASAに多数の「あじさい」のデータが集まるようになった。水路部がNASAから入手しているのもこれらのデータに基づくものである。

今述べたように NASA も「あじさい」の予報を行っている。その精度は，長い経験の蓄積もあってさすがに良い。

Table 3. The result of observations of Ajisai made by the institutes in Japan on the day of the launch

機関＼周回数	8	9	10	11	12	備考
国土地理院（鹿野山）	○	×	×	×	×	
東京天文台（堂平）光学	○	○	×	×	×	写真撮影
東京天文台（堂平）レーザー	×	○	×	○	×	
電波研究所	○	○	×	○	×	衛星追尾光学装置
宇宙科学研究所（内之浦）	×	×	×	×	×	天候不良の為観測不可 翌15日には観測できた
NASDA（種子島）	○	×	×	×	×	
同上（筑波）	○	×	×	×	×	
GSW（アマチュア天文家）*						
北海道			1	1		サブセンター計 2
東北	6	5	5	4		サブセンター計20
東京	2					サブセンター計 2
中部		23				サブセンター計23
近畿	8	3	1	1		サブセンター計13
中国						サブセンター計 0
四国						サブセンター計 0
九州	2	3			1	サブセンター計 6
その他		2	2			計 4
計	18	36	9	6	1	70

○：観測，×：観測不可，GSWの数値は取得できたデータ件数。

* Geodetic Satellite Watching アマチュア天文家によって組織されたもの。

NASDA：EGS 初期機能確認報告書（S61.10.7）による。

Table 4. The SLR observations of Ajisai made in the foreign observatories on the day and the next day of the launch

年 月 日	時 刻 (UT)	観 測 局	リターン数
1986 8 13	0^h 16^m 50^s - 0^h 17^m 40^s	RGO (英)	56
	3 53 22 - 3 56 20	Quincy (米)	377
	5 52 23 - 6 2 19	Quincy	1684
	9 55 3 - 10 7 27	Quincy	3212
	11 12 11 - 11 21 52	Yaragadee (豪)	2638
	11 57 14 - 12 11 2	Quincy	3591
	14 0 7 - 14 10 46	Quincy	2688
14	1 30 22 - 1 31 2	Zimmerwald (ス)	25
	2 2 36 - 2 14 43	Yaragadee	2909
	3 3 21 - 3 15 38	Maryland (米)	2289
	3 26 57 - 3 31 30	RGO	724
	4 55 14 - 5 8 0	Quincy	3506
	5 5 24 - 5 17 38	Maryland	1970
	6 58 59 - 7 10 11	Quincy	2749
	7 9 33 - 7 19 35	Maryland	1245
	9 0 31 - 9 12 48	Quincy	3364
	9 12 44 - 9 22 52	Maryland	1250
	11 3 10 - 11 16 38	Quincy	3610
	13 6 14 - 13 18 6	Quincy	3365

ＲＧＯ：王立グリニジ天文台
（ス）：スイス
ＲＧＯ，Zimmerwald 以外はＮＡＳＡの観測局。

Table 5. Monthly statistics of the observed passes of Ajisai at the foreign observatories in 1986

観　　測　　局		8月	9月	10月	11月	12月	計
Potsdam	(東独)	3	4	3	3	13	26
Haleakala	(米、ハワイ)	10	4	3	—	—	17
Bar Giyyora	(イスラエル)	7	4	12	9	3	35
Metsahobi	(フィンランド)	—	5	—	13	5	23
Zimmerwald	(スイス)	6	7	2	19	5	39
Wettzell	(西独)	—	4	6	25	—	35
Grasse	(仏)	—	—	8	40	24	72
Shanghai	(中国)	—	—	—	—	4	4
Graz	(オーストリア)	8	15	3	43	12	81
Herstmonceux (RGO)	(英)	14	42	25	29	16	126
Arequipa	(ペルー)	16	39	44	15	31	145
Matera	(伊)	23	45	23	31	28	150
Monument Peak	(米、カリフォルニア)	7	41	40	18	13	119
Yarragadee	(豪)	17	17	13	11	16	74
Mazatlan	(メキシコ)	4	20	13	2	1	40
Goddard	(米、メリーランド)	24	8	41	13	3	89
Quincy	(米、カリフォルニア)	39	14	16	15	6	90

このような状況であるため，世界の各観測局に水路部が直接予報を送ったり，データを即時入手するということは行われていないが，その連絡体制は打ち上げ前から整えられていた。国内的にはNASDA，水路部，国土地理院の三者協定（本巻1ページの記事参照）で明確に定められているほか，水路部と国内外の各機関との連絡網は図2. a，2. bに示すようになっていた。外国局に対する衛星打ち上げ前の予定軌道の要素の通知，打ち上げ直後の軌道の状況の通知において，この連絡網は有効に機能した。その後は前述したようにNASAを通じての通信が中心となっている。

本報告は久保良雄が作成した。

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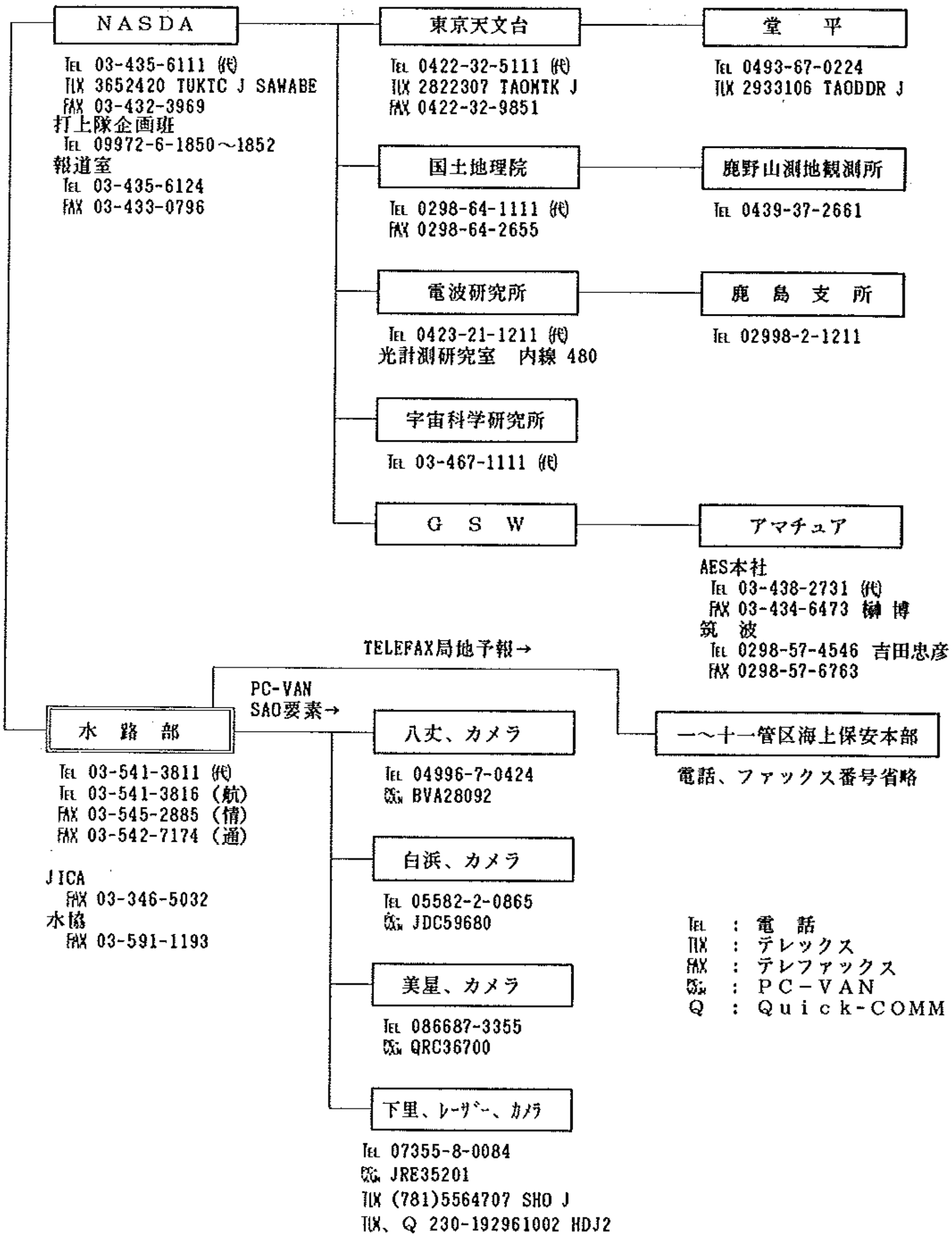

Figure 2.a. Communication network for Ajisai observation (Domestic)

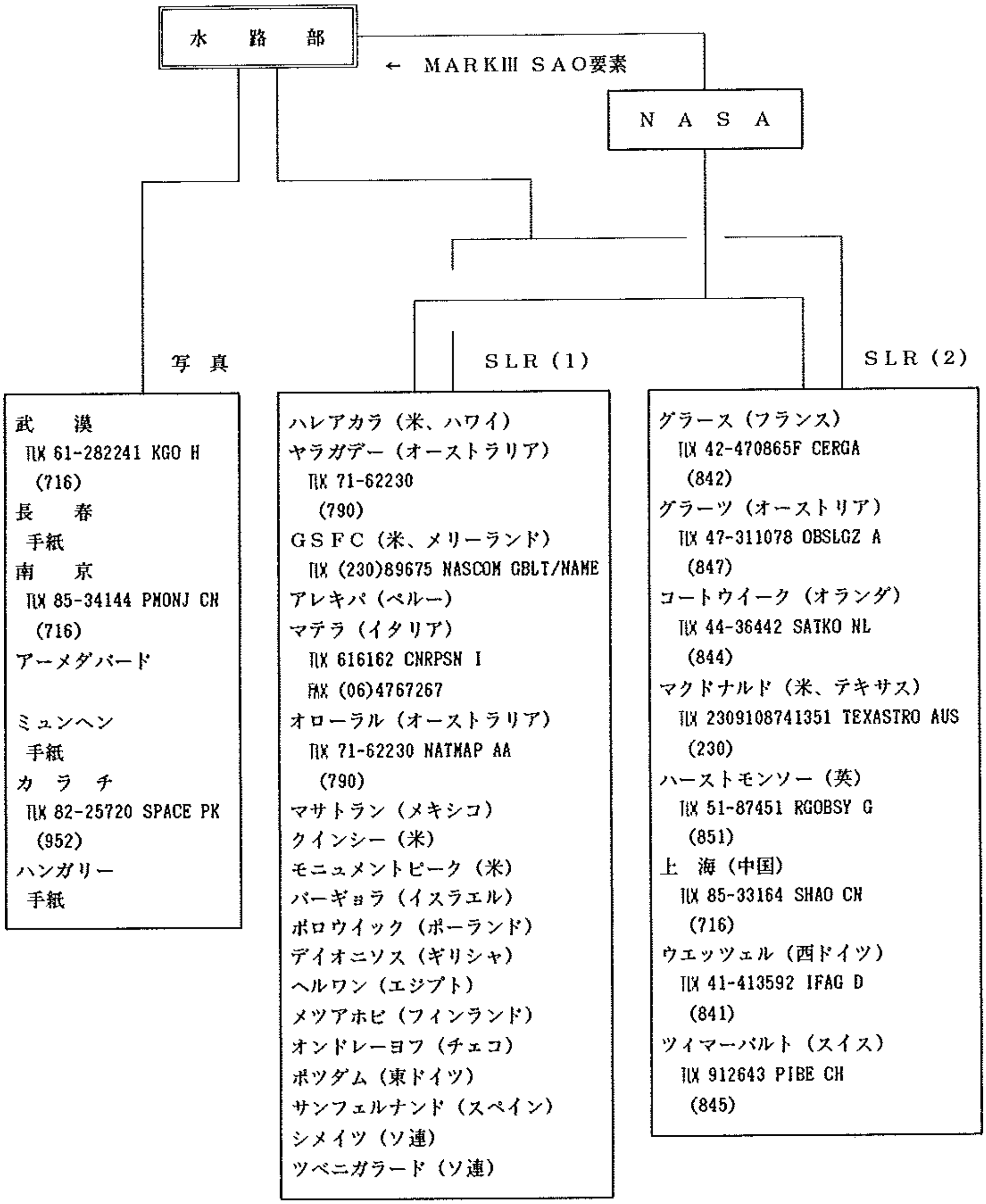

Figure 2. b. Communication network for Ajisai observation(International)

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