BUREAU INTERNATIONAL DES POIDS ET MESURES

Annual Report of the BIPM Time Section
Rapport annuel de la Section du temps du BIPM

Volume 2

1989

Pavillon de Breteuil
F - 92312 SÈVRES Cedex

ERRATUM

Annual Report of the BIPM Time Section, Volume 1, 1988

Page A-9, explanations for Table 9B, second paragraph,
read "Table 9B provides ..." instead of "Table 4 provides ..."

Page B-7, for AOS and PTB, the constant term of TA(k)-UTC(k) is
24.000... s instead of 23.000... s

Page B-7, for SU, read 21,172... instead of 20.172...

THE ORGANIZATION OF INTERNATIONAL SERVICES FOR TIME (TAI, UTC), EARTH ROTATION AND RELATED REFERENCE SYSTEMS

Until the 31st of December 1987, the Bureau International de l'Heure (BIH) was in charge of establishing the atomic time scales, International Atomic Time (TAI) and Coordinated Universal Time (UTC), and to evaluate the Earth rotation parameters. On the 1st of January 1988, these services were divided between the BIPM and a new service as explained in the following.

INTERNATIONAL ATOMIC TIME, TAI
COORDINATED UNIVERSAL TIME, UTC

The establishment of TAI and UTC (with the exception of the determination and the announcement of leap seconds of UTC) is placed under the responsibility of the Bureau International des Poids et Mesures (BIPM) and of the Comité International des Poids et Mesures (CIPM).

The periodic publications on Time of BIPM are :

- Circular T, monthly
- Annual Report of the BIPM Time Section.

Some of the data of the BIPM Time Section, as well as other information, are available by telephone line, either through the General Electric Mark 3 system or through the BIPM data service. Information concerning access to these services can be obtained on request from the BIPM.

Practical information

BIPM mailing address

Pavillon de Breteuil, F92312 Sèvres Cedex, France

Telephone
Switchboard + 33 1 45 07 70 70
Time Section + 33 1 45 07 70 72

Fax + 33 1 45 34 20 21

Telex BIPM 201067 F

EARTH ROTATION AND RELATED REFERENCE SYSTEMS

The International Earth Rotation Service (IERS), which started operation on the 1st of January 1988, is responsible for Earth rotation determinations and the maintainance of the related celestial and terrestrial reference systems. Information on IERS can be obtained from

Central Bureau of IERS (IERS/CB)
(Head: Dr. M. Feissel)
Observatoire de Paris
61, avenue de l'Observatoire
F75014 Paris, France

Telephone : + 33 1 40 51 22 26
Telex : OBS 270776 F

One of the tasks of IERS is the determination and the announcement of dates of occurrence of leap seconds of the UTC.

ORGANISATION DES SERVICES INTERNATIONAUX POUR LE TEMPS (TAI, UTC) ET LA ROTATION DE LA TERRE AINSI QUE LES SYSTEMES DE REFERENCE ASSOCIES

Jusqu'au 31 décembre 1987, le Bureau international de l'heure (BIH) avait la charge d'établir les échelles de temps atomique, Temps atomique international (TAI) et Temps universel coordonné (UTC), ainsi que d'évaluer les paramètres de la rotation terrestre. Le 1er janvier 1988, ces services ont été répartis entre le BIPM et un service nouvellement créé, comme cela est expliqué ci-après.

TEMPS ATOMIQUE INTERNATIONAL, TAI
TEMPS UNIVERSEL COORDONNE, UTC

L'établissement de TAI et de UTC (à l'exception de l'annonce des secondes intercalaires de l'UTC) est placé sous la responsabilité du Bureau international des poids et mesures (BIPM) et du Comité international des poids et mesures (CIPM).

Les publications périodiques du BIPM sur le temps sont :

- la Circulaire T, mensuelle,
- le Rapport annuel de la Section du temps du BIPM

Certains résultats des travaux de la Section du temps du BIPM, ainsi que d'autres informations, sont aussi disponibles par ligne téléphonique, soit par le système informatique General Electric Mark 3, soit par un service de données propre au BIPM. L'accès à ces services sera expliqué sur demande faite au BIPM.

Renseignements pratiques

Adresse postale du BIPM

Pavillon de Breteuil F92312 Sèvres Cedex, France

Téléphone
Standard + 33 1 45 07 70 70
Section du temps + 33 1 45 07 70 72

Télécopie + 33 1 45 34 20 21

Télex BIPM 201067 F

ROTATION DE LA TERRE
SYSTEMES DE REFERENCE ASSOCIES

Le Service international de la rotation terrestre (IERS), entré en fonction le 1er janvier 1988, est responsable de la détermination de la rotation terrestre et de la conservation des systèmes de référence terrestre et céleste associés. Les renseignements sur l'IERS et ses publications peuvent être obtenus à l'adresse suivante :

Bureau Central de l'IERS (IERS/CB)
(Directeur : Mme M. Feissel)
Observatoire de Paris
61, avenue de l'Observatoire
F75014 Paris, France

téléphone : + 33 1 40 51 22 26
Télex: OBS 270776 F

L'une des missions de l'IERS est le choix des dates et l'annonce des secondes intercalaires de l'UTC.

CONTENTS
TABLE DES MATIERES

PART C TIME SIGNALS (1989/90)
SIGNAUX HORAIRES (1989/90)

PART D SCIENTIFIC CONTRIBUTIONS

PART A

GENERAL INFORMATION

EXPLANATION OF TABLES

PARTIE A

INFORMATIONS GENERALES

EXPLICATION DES TABLEAUX

1 - ATOMIC TIME SCALES

ESTABLISHMENT OF INTERNATIONAL ATOMIC TIME AND COORDINATED UNIVERSAL TIME IN 1989

International Atomic Time (TAI) and Coordinated Universal Time (UTC) are obtained from a combination of atomic clocks and frequency standards data, as explained in part D of the Annual Report of the BIPM Time Section, Vol. 1, 1988.

We recall that, to this end, a stability algorithm ALGOS produces first a free atomic time scale, denoted EAL (Echelle atomique libre). The EAL is optimized for the stability of a two-month sample time. No attempt is made to ensure the conformity of the EAL unitary scale interval with the second of the International System of Units: this interval may diverge progressively from the second.

The duration of the unitary scale interval of EAL is evaluated from the data of primary cesium standards. Then TAI is derived from EAL by adding a linear function of time with a convenient slope to ensure the accuracy of the TAI unitary scale interval. The frequency offset between TAI and EAL is changed as necessary to maintain accuracy, the magnitude of the changes being of the same order as the frequency fluctuations resulting from the instability of EAL. This operation is often referred to as the "steering" of TAI.

TAI and UTC are made available in the form of time differences with respect to time scales kept by national laboratories "k": UTC(k), approximation to UTC, and TA(k), independent local atomic time.

These differences UTC - UTC(k), TAI - TA(k), are computed at 10-day intervals for Modified Julian Dates (MJD) terminating with a 9, at 0 h UTC, thereafter designated as "standard dates".

The computation of TAI has a basic periodicity of two months. However a provisional computation is made every other month (January, March, etc.) with the data which are available. The following month, TAI is recomputed for the whole span of two months. The deviations between the provisional one-month and complete two-month solutions are usually smaller than 10 ns. This organization allows the monthly publication of results in the BIPM Circular T.

When preparing the Annual Report, the results of Circular T are revised taking into account some improvements in the data made known after the publication of Circular T. The computations are then made strictly by six two-month batches.

In the following, and everywhere in this Report, the laboratories are designated by the acronyms explained in Table 1 of Part B.

Time links used by the BIPM in 1989

Figure 1 at the end of Section B shows the network of links used in 1989.

(a) LORAN-C links

The laboratories where only LORAN-C is received are linked to "pivot" laboratories where both LORAN-C and GPS are received. Simultaneous receptions of the LORAN-C signals have been organized.

The time differences of the UTC(k)'s of the laboratories are computed daily, then the values at the standard dates are evaluated by linear fit over 10 days (5 before and 5 after the standard date), except when time or frequency steps of the UTC(k)'s are reported or found.

The following LORAN-C time comparisons are evaluated by the BIPM and used in the TAI computations (end 1989):

FTZ	-	PTB
BEV	-	OP
PKNM	-	OP
SU	-	OP
CAO	-	IEN
YUZM	-	IEN
CSAO	-	TAO
JATC	-	TAO
NIM	-	TAO
SO	-	TAO
RC	-	USNO

(b) GPS links

The time comparisons are usually made by simultaneous tracking of satellites ("common views") according to schedules established by the BIPM.

However, in the BIPM evaluation of time comparisons, a "clock transportation mode" is sometimes applied. In this mode UTC(j) - GPS time and UTC(k) - GPS time are evaluated separately from the data of satellites which appear in these sites at their maximum of elevation, without requiring the simultaneity of the observations. By filtering and interpolating, daily values of these quantities are expressed at 0 h UTC. Then UTC(j) - UTC(k) is obtained by differences at the standard dates. The reasons for using this method are that

- it gives better results than the common views over very long distances (case TAO-OP),
- it allows a local treatment in participating laboratories and reduces the amount of data to be transmitted (cases DPT-OP and ONRJ-USNO),
- no common views are available (case PEL-TAO).

In the TAI computations, the following GPS links are used (end 1989):

IEN - OP		
IFAG - OP		
INPL - OP		
NPL - OP		
NPLI - OP		
ORB - OP		
PTB - OP		
ROA - OP		
STA - OP		
TAO - OP	computed by BIPM	
TUG - OP		
USNO - OP		
VSL - OP		
CRL - TAO		
KSRI - TAO		
NAOM - TAO		
NRLM - TAO		
PEL - TAO		
TL - TAO		

NRC - NIST	computed by NIST
USNO - NIST	

APL - USNO	computed by APL
AUS - USNO	computed by ORR
CH - PTB	computed by CH
DPT - OP	computed by DPT and BIPM
ONRJ - USNO	computed by ONRJ and BIPM

At the end of 1989, current measurements of the ionospheric delay, made at the CRL and the BIPM with dual frequency GPS receivers of the CRL type, were available. These data have been used for the link TAO-OP since the beginning of November 1989. In 1988, we attempted to evaluate the link USNO-OP with modelled values of the ionospheric delay for USNO-satellite and measured values for OP-satellite; this method appeared to be a source of biases and had been discontinued, the modelled values now being used for both legs.

For the laboratories IEN, IFAG, KSRI, NAOM, NPL, NRLM, OP, ORB, PTB, ROA, TAO, TUG, VSL, corrections to the adopted coordinates of the antennas have been applied. These were derived from the time comparisons themselves [Guinot, B., Lewandowski, W., 'Improvement of the GPS time comparisons by simultaneous relative positioning of the antennas', Bull. géod. 63 (1989), pp. 371-386].

(c) Other links

The simultaneous reception of public television signals provides the links

PTB - ASMW
ASMW - ZIPE
ZIPE - AOS
PTB - TP
TP - OMH.

Accuracy of the TAI scale interval

Table A gives the normalized frequency offsets between EAL and TAI. The relationship TAI-EAL was modified twice in 1989, by frequency offsets of 0.5 x 10^{-14} in order to compensate a frequency drift of EAL with respect to the primary standards of the PTB.

Table A - Differences between the normalized frequencies of EAL and TAI (until January 1990)

Date	MJD	f(EAL) - f(TAI) in 10^{13}
until 1977 JAN 1	until 43144	0
1977 JAN 1 - 1977 APR 26	43144 - 43259	10.0
1977 APR 26 - 1977 JUN 25	43259 - 43319	9.8
1977 JUN 25 - 1977 AUG 24	43319 - 43379	9.6
1977 AUG 24 - 1977 OCT 23	43379 - 43439	9.4
1977 OCT 23 - 1978 OCT 28	43439 - 43809	9.2
1978 OCT 28 - 1979 JUN 25	43809 - 44049	9.0
1979 JUN 25 - 1979 AUG 24	44049 - 44109	8.8
1979 AUG 24 - 1979 OCT 23	44109 - 44169	8.6
1979 OCT 23 - 1982 APR 30	44169 - 45089	8.4
1982 APR 30 - 1982 JUN 29	45089 - 45149	8.2
1982 JUN 29 - 1982 AUG 28	45149 - 45209	8.0
1982 AUG 28 - 1984 FEB 29	45209 - 45759	7.8
1984 FEB 29 - 1987 APR 24	45759 - 46909	8.0
1987 APR 24 - 1987 DEC 30	46909 - 47159	8.0125
1987 DEC 30 - 1989 JUN 22	47159 - 47699	8.0
1989 JUN 22 - 1989 DEC 29	47699 - 47889	7.95
1989 DEC 29 -	47889 -	7.90

As the time scales UTC and TAI differ by an integral number of seconds (see Tables 2 and 3), UTC is necessarily subject to the same intentional frequency adjustement as TAI.

TIME SCALES ESTABLISHED IN RETROSPECT

For the most demanding applications, such as millisecond pulsar timing, the BIPM issues atomic time scales in retrospect designated as TT(BIPMxx) where 1900 + xx is the year of the computation. The successive versions of TT(BIPMxx) are both updates, and revisions: they may differ for common dates.

The principles of establishment of TT(BIPMxx) are described by Guinot, B. in "Atomic time scales for pulsar studies and other demanding applications, Astron. and Astrophys., 192, 1988, pp. 370-373".

These time scales are available on request from the BIPM.

EXPLANATIONS OF THE TABLES

TABLE 1

ATOMIC TIME, COLLABORATING LABORATORIES

The table lists the laboratories contributing data on atomic time, with the abbreviations used in this Report.

TABLE 2

FREQUENCY OFFSETS AND STEP ADJUSTMENTS OF UTC

From 1961 January 1 to 1990 June 30.

TABLE 3

RELATIONSHIP BETWEEN TAI AND UTC

From 1961 January 1 to 1990 June 30.

TABLE 4

LABORATORIES KEEPING AN INDEPENDENT LOCAL ATOMIC TIME

The Table gives, for 1989, the equipment of the laboratories which compute an independent local atomic time TA(k) and the relationship between TA(k) and UTC(k) (or the references for finding the values of TA(k)-UTC(k)).

TABLE 5

EQUIPMENT AND TIME LINKS OF THE COLLABORATING LABORATORIES

The Table shows the equipment (number and type of clocks) and the time links available in the collaborating laboratories in 1989. See also figure 1, end of section B.

TABLE 6

ABSOLUTE TIME COMPARISONS BETWEEN LABORATORIES

A. Clock transportation

Unless otherwise stated, the transportation was carried out by the first mentioned laboratory.

B. GPS time comparisons with differential calibration of receiver delays.

No measurements of this type have been reported to the BIPM for 1989.

TABLE 7

INDEPENDENT LOCAL ATOMIC TIME SCALES

The Table gives the values of TAI-TA(k) for laboratories k where independent atomic times TA(k) are established. The data are rounded to 10 ns for laboratories using LORAN-C and television links.

TABLE 8

PRIMARY FREQUENCY STANDARDS USED AS CLOCKS

Five primary frequency standards were used as clocks in 1989: Cs V, Cs VIA, Cs VIC of NRC, CS1 and CS2 of PTB. Table 8 gives TAI-standard.

TABLE 9

COORDINATED UNIVERSAL TIME

The Table gives the value of UTC-UTC(k), where UTC(k) designates the approximation to UTC kept by the laboratory k. The values are based on permanent links: GPS, LORAN-C, television. The data are rounded to 10 ns for the laboratories using LORAN-C and television links.

TABLE 9B

TAI-GPS TIME AND UTC-GPS TIME

The GPS satellites which appear in this section disseminate, to within about ± 20 ns (1 σ), a common time scale designated here as "GPS time". The relation between GPS time and TAI is

$$TAI - GPS\ time = 19\ s + Co,$$

where the time difference of 19 seconds is kept constant and Co is a quantity of the order of a few microseconds, varying with time. The relation between GPS time and UTC involves a variable number of seconds as a consequence of the leap seconds of the UTC system and is as follows.

1989 January 1 - 1990 January 1, 0 h UTC	UTC - GPS time = - 5 s + Co
1990 January 1, 0 h UT - until the introduction of the next leap second	UTC - GPS time = - 6 s + Co

Table 9B provides Co at 0 h UTC every day. In most applications TAI and UTC can be derived from the tracking of any of the listed satellites, at any time, by interpolating Co.

The synchronisation offset between satellites, DC, as measured at the Paris Observatory, is also given at T, the time of the day corresponding to the tracking schedule at the Paris Observatory. The time T is given at the top of the table for the first tabular date; it must be decremented by 4 minutes per day (8 minutes when moving from 0 h ... to 23 h ...). When the synchronisation offset is large, it might be possible to improve the access to TAI and UTC by replacing Co by Co + DC. The values of Co and DC are computed using the best available coordinates in WGS 84, and, since November 1988, with measured ionospheric delays.

GPS(i) being the time disseminated by GPS satellite i, at the time T(i) of its observation at Paris Observatory, one has strictly

$$UTC(OP) - GPS(i) = - 5\ s + Co + DC - [UTC - UTC(OP)],$$

Co and UTC-UTC(OP) being interpolated linearly for T(i).

TABLE 10

COMPARISON BETWEEN ABSOLUTE TIME COMPARISONS AND THE BIPM RESULTS

For the time comparisons listed in Table 6, Table 10 gives the residuals "measurement minus BIPM data". The BIPM data are deduced from Table 9.

TABLE 11

INTERNATIONAL ATOMIC TIME, BI-MONTHLY RATES OF TAI-CLOCK FOR 1989

The mean rates for intervals of two months are given for all the clocks which participated in the TAI computation in 1989. Similar tables are published in the Annual Report for 1988 and in the BIH Reports from 1973 to 1987.

When an intentional frequency adjustement has been applied to a clock, the data prior to this adjustment are corrected, so that Table 11 gives homogeneous rates for the whole of the year 1989. However for studies including the rates of previous years, corrections must be brought to the data of Annual Report of 1988 and of the BIH Annual Reports for the previous years. These corrections are given by Table B.

When the operation of a clock is resumed after an interruption, marked*** in Tables 11 and 12, it is considered as a new clock.

TABLE 12

INTERNATIONAL ATOMIC TIME, WEIGHTS OF THE CLOCKS FOR 1989

It should be remembered that the weights have an assigned upper limit. From 1988 January 1st, date of the change of the weighting procedure, as explained in Part D of the Annual Report for 1988, the maximum weight has been 100, which corresponds to a relative weight of about 2,1 %.

Clock data used at BIPM are obtained by intercomparison methods, so the Table reflects the combined instability of the clock and of the time intercomparison. On the other hand, the weights of Table 12 correspond to the long term stability of the clocks (2 months sample time) which is, in particular, dependent on the conditions of operation. For these two reasons, the weights should not be used as a general factor of quality for these clocks.

TABLE B - Corrections for an homogeneous use of the bi-monthly rates and weights published in the current and previous Annual Reports. Each line refers to the same clock working without interruption.

Lab.	1989 clock n°	1988 clock n°	1988 corr. (ns/d)	1987 clock n°	1987 corr. (ns/d)	1986 clock n°	1986 corr. (ns/d)
CSAO	12 1646	12 1646		12 1646	+41.60	12 1646	+41.60
	12 1647	12 1647		12 1647		12 1647	+20.60
	12 1648	12 1648		12 1648		12 1648 (1)	+98.60
FTZ	14 1674	14 1674		14 1674		14 1674 (2)	
NIM	12 1615	12 1615		12 1615		12 1615 (3)	-940.67
NIST	12 352	12 352		12 352		12 352	+17.00
	14 323	14 323		14 323	-6.84	14 323	-6.84
	14 601	14 601	+18.75				
ROA	14 1569	14 1569		14 1569	-13.00	14 1569	-13.00
	16 177	16 177		16 177	+46.00	16 177 (4)	+46.00
USNO	14 2314	14 2314		14 2314	+31.00		

(1) A correction of +98.60 ns/d has to be applied in 1985.

(2) A correction of -19.50 ns/d has to be applied for the last four two-month intervals of 1982.

(3) A correction of -940.67 ns/d has to be applied in 1985 and for the last two-month intervals of 1984.

(4) A correction of +46.00 ns/d has to be applied in 1985 and for the last two-month intervals of 1984.

Table C contains some statistical data on the clocks which participated in the TAI computations for 1989.

Table C Statistical data on the weights attributed to the clocks in 1989.

Interval 1989	Total Number of clocks	weights 0*	weights 0**	weight 1-19	weight 20-39	weight 40-59	weight 60-79	weight 80-99	weight 100
		Number of clocks with a given weight							
JAN-FEB	175	34	16	70	23	7	3	1	21
MAR-APR	178	30	5	82	20	11	6	4	20
MAY-JUN	177	24	8	78	22	10	6	3	26
JUL-AUG	170	23	14	65	20	10	9	6	23
SEP-OCT	171	30	16	56	25	11	4	2	27
NOV-DEC	175	29	15	66	22	8	7	2	26

* A priori null weights (test interval of new clocks).
** Null weights resulting from the statistics.
Clocks with missing data during a two-month interval of computation are excluded.

TABLE 13

MEASUREMENTS OF THE EAL AND TAI FREQUENCY

Table 13 gives the differences which were measured in 1984-1989 between the normalized frequencies of EAL and TAI and of the laboratory cesium standards CRL-Cs1, NIST-6, NRC-CsV, NRC-CsVI-A, B, C, PTB-CS1, PTB-CS2, SU-MCsR 101, SU-MCsR 102.

The standard NIST-6 (previously NBS6) is operated in discontinuous mode. The calibration data, referred to UTC(NIST) are transferred to EAL and TAI by a linear adjustment of EAL-UTC(NIST) over 80 days.

The standard NRC-CsV has been working as a clock since May 1975. The EAL and TAI calibrations result from a linear adjustment of EAL-standard over 60-day intervals.

The standards NRC-CsVI-A, C have been used as clocks since the end of 1979 and the calibration data are transferred to EAL as for NRC-CsV. The standard NRC-Cs VI-B was used as clock from the end of 1979, until the beginning of 1988.

The standard PTB-CS1 was used as a frequency reference operating discontinuously until July 1978. Since then it has been running as a clock, and the calibrations are obtained as for NRC-CsV.

The standard PTB-CS2 runs as a clock. The data starting from August 1986 were received at BIH and used in the same way as those of PTB-CS1.

The standard CRL-Cs1 (previously RRL-Cs1) performs discontinuous calibrations of UTC(CRL) which are transferred to EAL by linear adjustment of EAL-UTC(CRL) over 60 days.

The standards SU-MCsR 101 and SU-MCsR 102 provide the frequency of TA(SU) and UTC(SU). The transfer to EAL is made by averaging the frequency difference of TA(SU) and EAL over several months.

TABLE 14

MEAN DURATION OF THE TAI SCALE INTERVAL IN SI SECOND AT SEA LEVEL

The estimate is made by the BIPM with the filter described in "Azoubib J., Granveaud M., Guinot B., Metrologia 13, 1977, pp. 87-93". It is based on the calibrations of Table 13. Special care has been taken so that the seasonal frequency variation which is observed between EAL and the primary standards is not smoothed out.

2 - TIME SIGNALS

Part C of the Report (yellow pages) contains information on the time signal emissions in the UTC system.

a - Until 1971 December 31, 23 h 59 m 60.1077580 s, UTC (old), the relationship between UTC and TAI included an internationally agreed frequency offset. Tables 2 and 3 of Part B give the relationship.

b - At the above-mentioned date, a time-step of - 0.1077580 s was applied to UTC and this date became 1972 January 1, 0 h UTC (new) exactly. The new UTC is such that TAI-UTC must equal an integral number of seconds, in accordance with Recommendation 460-4 (1986) of the International Radio Consultative Committee (CCIR).

The information on the time signals is based on the answers to a questionnaire of February 1990. More detailed information may be obtained from the addresses listed on pages C2 - C4.

3 - BIPM TIME SECTION

The following persons participated in the activities of the BIPM time section, in 1989:

Prof.	B.	Guinot,	Head
Dr.	C.	Thomas,	Physicist
Dr.	W.	Lewandowski,	"
Mr.	J.	Azoubib,	"
Miss	H.	Konaté,	Technician
Mrs	M.	Thomas,	Technician
Mrs	P.	Tavella*,	Visitor (October-December 1989)

* Mrs P. Tavella belongs to the Istituto Elettrotecnico Nazionale Galileo Ferraris, Torino, Italy.

1 - ECHELLES DE TEMPS ATOMIQUE

ETABLISSEMENT DU TEMPS ATOMIQUE INTERNATIONAL ET DU TEMPS UNIVERSEL COORDONNE EN 1989

Le Temps atomique international (TAI) et le Temps universel coordonné (UTC) sont obtenus par une combinaison de données d'horloges atomiques et d'étalons primaires de fréquence, comme cela est expliqué, partie D du Rapport annuel de la Section du temps du BIPM, vol. 1, 1988.

Nous rappelons que, pour cela, un algorithme de stabilité ALGOS produit d'abord une "échelle atomique libre" (EAL) qui est optimisée pour la stabilité sur 2 mois. Il n'est pas tenté d'assurer la conformité de l'intervalle unitaire de l'EAL avec la seconde du Système international d'unités, elle peut en diverger lentement, mais indéfiniment.

La durée de cet intervalle unitaire de l'EAL est évaluée à partir des données d'étalons de fréquence à césium primaires. Ensuite le TAI se déduit de l'EAL par l'addition d'une fonction linéaire du temps dont la pente est convenablement choisie pour assurer l'exactitude de l'intervalle unitaire du TAI. Le décalage de fréquence entre le TAI et l'EAL est changé quand c'est nécessaire pour maintenir l'exactitude, les changements ayant le même ordre de grandeur que les fluctuations de fréquence qui résultent de l'instabilité de l'EAL. Cette opération est souvent désignée par l'expression "pilotage du TAI".

Le TAI et l'UTC sont disponibles sous forme de différences de temps avec les échelles de temps conservées par des laboratoires horaires nationaux "k" : UTC(k), approximation de UTC, et TA(k), temps atomique local indépendant.

Les différences UTC - UTC(k), TAI - TA(k), sont calculées de 10 jours en 10 jours pour les dates juliennes modifiées (MJD) se terminant par 9, à 0 h UTC, "dates normales".

Le calcul du TAI doit être fait, en principe, tous les deux mois. Mais un calcul provisoire est fait un mois sur deux (pour janvier, mars, ...) avec les données disponibles. Le mois suivant, le calcul du TAI est repris pour une durée de deux mois. L'écart entre les résultats des calculs provisoires et complets est ordinairement inférieur à 10 ns. Cette organisation permet la publication mensuelle des résultats dans la Circulaire T du BIPM.

Quand le Rapport annuel est préparé, les résultats de la circulaire T sont révisés, compte-tenu d'améliorations des données, connues après la publication de la Circulaire T. Les calculs sont alors strictement faits par période de deux mois.

Dans la suite et dans tout ce rapport, les laboratoires sont désignés par les sigles expliqués dans la table 1 de la partie B.

Liaisons horaires utilisées par le BIPM en 1989

Ces liaisons montrées, par la figure 1 de la section B, procurent les différences entre les UTC(k) des laboratoires participants, pour les dates normales. Elles sont établies

- par le LORAN-C,
- par le Global Positioning System, GPS,
- par la réception d'impulsions de la télévision publique.

Dans toutes ces méthodes on fait appel généralement à la réception simultanée des signaux et l'on recherche la meilleure estimation des différences des UTC(k) aux dates normales.

L'ensemble des liaisons utilisées est donné dans le texte anglais qui précède. Il est sans redondance.

Pour la liaison par GPS entre TAO et OP, on a utilisé, à partir du début de novembre 1989, les mesures de retards ionosphériques faites au CRL et au BIPM à l'aide de récepteurs bi-fréquence du type du CRL. Par contre, on a cessé d'employer les mesures faites au BIPM pour le lien USNO-OP, car leur utilisation sur la seule branche OP-satellite était une cause d'erreur systématique.

Les liaisons par GPS en Europe, en Extrême- Orient et entre ces régions ont été améliorées par l'usage de coordonnées géodésiques déterminées au BIPM à partir des comparaisons horaires elles-mêmes et par d'autres moyens.

Exactitude de l'intervalle unitaire du TAI

Le tableau A (texte anglais) donne le décalage de fréquence entre le TAI et l'EAL. La relation entre le TAI et l'EAL a été modifée deux fois en 1989, par des décalages de fréquence de $0{,}5 \times 10^{-14}$, afin de compenser une dérive de fréquence de l'EAL par rapport aux étalons primaires de la PTB.

ECHELLES DE TEMPS ETABLIES RETROSPECTIVEMENT

Pour les applications les plus exigeantes, comme le chronométrage des pulsars à la milliseconde, le BIPM produit des échelles de temps rétrospectivement, désignées par TT(BIPMxx), 1900 + xx étant l'année du calcul. Les versions successives de TT(BIPMxx) ne sont pas seulement des mises à jour, mais aussi des révisions, de sorte qu'elles peuvent différer pour les dates communes.

Les principes de l'établissement du TT(BIPMxx) ont été décrits par Guinot, B. dans "Atomic time scales for pulsar studies and other demanding applications, Astron. and Astrophys., 192, 1988, pp. 370-373".

Ces échelles de temps sont disponibles sur demande faite au BIPM.

EXPLICATION DES TABLEAUX

TABLEAU 1

TEMPS ATOMIQUE, LABORATOIRES COOPERANTS

Abréviations utilisées dans ce rapport.

TABLEAU 2

DECALAGES DE FREQUENCE ET AJUSTEMENTS PAR SAUT DE L'UTC

De 1961 janvier 1 à 1990 juin 30.

TABLEAU 3

RELATION ENTRE LE TAI ET L'UTC

De 1961 janvier 1 à 1990 juin 30.

TABLEAU 4

LABORATOIRES CONSERVANT UN TEMPS ATOMIQUE LOCAL INDEPENDANT

Le tableau indique, pour 1989, l'équipement des laboratoires qui calculent une échelle de temps atomique local indépendant TA(k) et la relation entre TA(k) and UTC(k) (ou la référence des documents où se trouve cette relation).

TABLEAU 5

EQUIPEMENT ET LIAISONS HORAIRES DES LABORATOIRES COOPERANTS

Le tableau indique l'équipement (nombre et type des horloges) et les liaisons horaires dont disposaient les laboratoires coopérants en 1989.

TABLEAU 6

COMPARAISONS DE TEMPS ABSOLUES ENTRE LABORATOIRES

A. Transports d'horloges

Sauf mention contraire, le transport a été effectué par le laboratoire mentionné en premier.

B. Comparaisons horaires par le GPS avec étalonnage des retards relatifs des récepteurs.

Il n'y a pas de mesures de ce type en 1989

TABLEAU 7

TEMPS ATOMIQUES LOCAUX INDEPENDANTS

Le tableau donne les valeurs de TAI-TA(k) pour les laboratoires k où des temps atomiques locaux indépendants TA(k) sont établis. Les valeurs sont arrondies à 10 ns pour les laboratoires utilisant le LORAN-C ou des liaisons par télévision.

TABLEAU 8

ETALONS PRIMAIRES DE FREQUENCE UTILISES COMME HORLOGES

Cinq étalons primaires de fréquence ont été utilisés comme horloges en 1989 : CsV, Cs VI-A, Cs VI-C du NRC, CS1 et CS2 de la PTB. Le tableau 8 donne TAI-étalon.

Les échelles de temps délivrées pour les étalons du NRC n'ont subi aucune correction pour le décalage gravitationnel de fréquence. Pour exprimer leur marche au niveau de la mer, il faut ajouter une correction de - 0,000 97 µs/jour.

Au contraire les échelles de temps délivrées par les étalons de la PTB sont converties en temps-coordonnée suivant la même définition que le TAI. La correction de marche qui leur a été appliquée est - 0,000 66 µs/jour.

TABLEAU 9

TEMPS UNIVERSEL COORDONNE

Le tableau donne les valeurs de UTC-UTC(k), où UTC(k) désigne l'approximation du UTC qui est conservée par le laboratoire k. Ces valeurs reposent sur des liaisons horaires permanentes, par GPS, LORAN-C, et télévision. Les valeurs sont arrondies à 10 ns pour le LORAN-C et la télévision.

TABLEAU 9B

UTC-TEMPS DU GPS ET TAI-TEMPS DU GPS

Les satellites du Global Positioning System (GPS) qui figurent dans cette rubrique diffusent à une ou deux dizaines de nanosecondes près une échelle de temps commune appelée ici "temps du GPS". La relation de cette échelle avec TAI est

$$\text{TAI - temps du GPS} = 19\ \text{s} + \text{Co},$$

où l'intervalle de 19 secondes est constant et où Co est une quantité de l'ordre de quelques microsecondes, variable avec le temps. On a aussi

de 1989 janvier 1 à 1990 janvier 1, 0 h UTC
UTC-temps du GPS = - 5 s + Co
de 1990 janvier 1, 0 h UTC, jusqu'à l'introduction
d'une nouvelle seconde intercalaire UTC-temps du GPS = - 6 s + Co.

Le tableau 9B donne Co pour chaque jour à 0 h UTC. Pour la plupart des applications il suffit de déduire le TAI et l'UTC de l'observation de n'importe quel satellite du tableau, à n'importe quel instant, par interpolation de Co.

L'écart de synchronisation entre satellites, DC, tel qu'il est mesuré à l'Observatoire de Paris est aussi fourni pour chaque jour à une heure T particulière à chaque satellite (qui correspond aux observations programmées à l'Observatoire de Paris). L'heure T est donnée en haut du tableau pour la première date tabulée ; elle doit être diminuée de 4 minutes par jour (8 minutes quand on passe de 0 h ... à 23 h ...). Dans les cas où l'écart de synchronisation est important, on peut espérer améliorer l'accès au TAI et à l'UTC en remplacant Co par Co + DC. Pour calculer Co et DC, on a tenu compte des meilleures coordonnées connues dans le WGS 84 pour l'antenne du récepteur et de valeurs mesurées de la réfraction ionosphérique à partir de novembre 1988.

GPS(i) étant le temps diffusé par le satellite i du GPS, à l'instant T(i) de son observation à l'Observatoire de Paris, on a strictement

$$\text{UTC(OP)} - \text{GPS(i)} = -5\ \text{s} + \text{Co} + \text{DC} - [\text{UTC} - \text{UTC(OP)}],$$

Co et UTC-UTC(OP) étant interpolés linéairement pour T(i).

TABLEAU 10

COMPARAISON ENTRE LES COMPARAISONS DE TEMPS ABSOLUES ET LES RESULTATS DU BIPM

Pour les comparaisons de temps figurant au tableau 6, le tableau 10 donne les résidus "mesure moins données du BIPM". Les données du BIPM sont obtenues par interpolation du tableau 9.

TABLEAU 11

TEMPS ATOMIQUE INTERNATIONAL, MARCHES BIMESTRIELLES DE TAI-HORLOGE POUR 1989

Les marches moyennes sur des intervalles de deux mois sont données pour toutes les horloges qui ont participé à l'établissement du TAI en 1989. On trouvera des tables similaires dans le Rapport annuel pour 1988 et dans les rapports du Bureau international de l'heure, de 1973 à 1987.

Quand la fréquence d'une horloge a été intentionnellement changée, les données qui précèdent ce changement ont été corrigées, de sorte que le tableau 11 fournit des marches homogènes pour toute l'année 1989. Cependant, dans des études qui incluent les années antérieures, des corrections doivent être apportées aux tableaux correspondants du Rapport annuel pour 1988 et des Rapports annuels du BIH pour 1987 et auparavant. Ces corrections sont données dans le tableau B (texte anglais).

Quand le fonctionnement d'une horloge reprend après une interruption, marquée par *** dans les tableaux 11 et 12, elle est considérée comme une horloge nouvelle.

TABLEAU 12

TEMPS ATOMIQUE INTERNATIONAL, POIDS DES HORLOGES POUR 1989

On rappelle que l'on a assigné aux poids statistiques des horloges une limite supérieure. Depuis le 1er janvier 1988, date du changement de pondération, comme il est expliqué dans la partie D du Rapport annuel pour 1988, le poids maximal est de 100.

Une horloge apparaît au BIPM à travers les méthodes de comparaison de temps. Par suite, le tableau 12 reflète l'instabilité combinée de l'horloge et de ces comparaisons de temps. D'autre part, les poids du tableau 12 correspondent à la stabilité de fréquence à long terme, sur des échantillons de deux mois, qui dépend, en particulier, des conditions dans lesquelles l'horloge fonctionne. Pour ces deux raisons, les poids ne doivent pas être utilisés comme un témoin général de la qualité des horloges.

Le tableau C (texte anglais), contient quelques données statistiques sur les horloges qui ont participé à l'établissement du TAI en 1989.

TABLEAU 13

MESURES DE LA FREQUENCE DE L'EAL ET DU TAI

Le tableau 13 donne les différences entre les fréquences mesurées d'EAL et du TAI et celles des étalons à césium primaires des laboratoires : CRL-Cs1, NIST-6, NRC-CsV, NRC-CsVI-A, B, C, PTB-CS1, PTB-CS2, SU-MCsR 101, SU-MCsR 102.

L'étalon NIST-6 (antérieurement NBS6) fonctionne en mode discontinu. Les résultats d'étalonnage, rapportés à UTC(NIST) sont transférés à l'EAL et au TAI par ajustement linéaire de EAL-UTC(NIST) sur 80 jours.

L'étalon NRC-CsV fonctionne comme horloge depuis mai 1975. Les résultats d'étalonnage de l'EAL et du TAI proviennent d'ajustements linéaires de EAL-étalon sur des intervalles de 60 jours.

Les étalons NRC-CsVI-A, C fonctionnent comme horloges depuis fin 1979. Les étalonnages sont obtenus comme ceux de NRC-CsV. L'étalon NRC-Cs VI-B a fonctionné de la fin 1979 au début 1988.

L'étalon PTB-CS1 a fonctionné d'une manière discontinue jusqu'en juillet 1978. Depuis, il fonctionne en horloge et les étalonnages de l'EAL et du TAI sont obtenus comme ceux de NRC-CsV.

L'étalon PTB-CS2 fonctionne comme horloge. Ses données ont été reçues par le BIH puis le BIPM depuis août 1986. Elles sont utilisées comme celles de PTB-CS1.

L'étalon CRL-Cs1 (antérieurement RRL-Cs1) donne d'une manière discontinue, la fréquence de UTC(CRL). Ces étalonnages sont transférés à l'EAL et au TAI par ajustement linéaire de EAL-UTC(CRL) sur 60 jours.

Les étalons SU-MCsR 101 et SU-MCsR 102 donnent la fréquence de TA(SU) et UTC(SU). Le transfert à l'EAL et au TAI repose sur un calcul de la différence de fréquence moyenne de EAL et TA(SU) sur plusieurs mois.

TABLEAU 14

DUREE MOYENNE DE L'INTERVALLE UNITAIRE DU TAI EN SECONDES DU SI AU NIVEAU DE LA MER

L'estimation utilise le filtre décrit dans "Azoubib J., Granveaud M., Guinot B., Metrologia 13, 1977, pp. 87-93", avec les étalonnages du tableau 13. Un soin particulier a été apporté pour que les variations saisonnières qui ont été observées entre l'EAL et les étalons primaires ne soient pas réduites par lissage.

2 - SIGNAUX HORAIRES

La partie C du rapport (pages jaunes) donne les principales caractéristiques des émissions de signaux horaires dans le système du UTC.

a - Jusqu'en 1971 décembre 31, 23 h 59 m 60,1077580 s, UTC (ancien), la relation entre l'UTC et le TAI comprenait un décalage de fréquence convenu. Les tableaux 2 et 3 de la partie B donnent cette relation.

b - A la date mentionnée ci-dessus, un saut de temps de - 0,1077580 s a été appliqué à l'UTC, de sorte que cette date est devenue 1972 janvier 1, 0 h UTC (nouveau) exactement. Le nouveau UTC est tel que TAI-UTC soit égal à un nombre entier de secondes, en accord avec la Recommandation 460-4 (1986) du Comité consultatif international des radiocommunications (CCIR).

Les renseignements sur les signaux horaires proviennent de réponses à notre enquête de février 1990. Des renseignements plus détaillés peuvent être obtenus aux adresses données par les pages C2 à C4.

3 - SECTION DU TEMPS DU BIPM

Les personnes suivantes ont participé aux travaux de la section du temps, en 1988

Mr	B.	Guinot,	Responsable
Mme	C.	Thomas,	Physicien
Mr	W.	Lewandowski,	"
Mr	J.	Azoubib,	"
Mlle	H.	Konaté,	Technicien
Mme	M.	Thomas,	Technicien
Mme	P.	Tavella*,	Stagiaire (octobre à décembre 1989)

* Mme P. Tavella est employée par l'Istituto Elettrotecnico Nazionale Galileo Ferraris, Turin, Italie.

PART B

TABLES AND FIGURES

PARTIE B

TABLEAUX ET FIGURES

TABLE 1 - ATOMIC TIME, COLLABORATING LABORATORIES

AOS	Astronomical Latitude Observatory, Borowiec, Polska
APL	Applied Physics Laboratory, Laurel, USA
ASMW	Amt für Standardisierung, Messwesen und Warenprüfung, Berlin, Deutsche Demokratische Republik
ATC	Australian Telecommunications Commission, Melbourne, Australia
AUS	Consortium of laboratories in Australia
BEV	Bundesamt für Eich - und Vermessungswesen, Wien, Oesterreich
BAO	Beijing Observatory, Beijing, P.R. China
CAO	Astronomical Observatory of Cagliari University, Cagliari, Italy
CH	Consortium of laboratories in Switzerland (see Table 4)
CRL	Communications Research Laboratory, Tokyo, Japan (formerly RRL)
CSAO	Shaanxi Astronomical Observatory, Lintong, P.R. China
DDR	Consortium of laboratories in Deutsche Demokratische Republik
DPT	Division of Production Technology, CSIR, Pretoria, South Africa (formerly NPRL)
F	Commission Nationale de l'Heure, Paris, France (see Table 4)
FTZ	Fernmeldetechnisches Zentralamt, Darmstadt, Bundesrepublik Deutschland
IEN	Istituto Elettrotecnico Nazionale Galileo Ferraris, Torino, Italia
IFAG	Institut für Angewandte Geodäsie, Frankfurt am Main, Bundesrepublik Deutschland
IGMA	Instituto Geografico Militar, Buenos-Aires, Argentina
INPL	National Physical Laboratory, Jerusalem, Israel
INTI	Instituto Nacional de Tecnologia Industrial, Buenos-Aires, Argentina
JATC	Joint Atomic Time Commission, Lintong, Shaanxi, P. R. China
KSRI	Korea Standards Research Institute, Taejon, Ch'ungnam, Rep. of Korea
NAOM	National Astronomical Observatory, Misuzawa, Japan (formerly ILOM)
NIM	National Institute of Metrology, Beijing, P.R. China
NIST	National Institute of Standards and Technology, Boulder, USA (formerly NBS)
NML	National Measurement Laboratory, CSIRO, Sydney, Australia
NPL	National Physical Laboratory, Teddington, U.K.
NPLI	National Physical Laboratory, New-Delhi, India
NRC	National Research Council of Canada, Ottawa, Canada
NRLM	National Research Laboratory of Metrology, Ibaraki, Japan
OMH	Orszagos Mérésügyi Hivatal, Budapest, Hungary
ONBA	Observatorio Naval, Buenos-Aires, Argentina
ONRJ	Observatorio Nacional, Rio de Janeiro, Brazil
OP	Observatoire de Paris, Paris, France
ORB	Observatoire Royal de Belgique, Bruxelles, Belgique
ORR	Orroral Observatory, Australia (formerly DNM)
PEL	Physics and Engineering Laboratory, Lower Hutt, New Zealand
PKNM	Polski Komitet Normalizacji Miar I Jakosci, Warszawa, Polska
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig, Bundesrepublik Deutschland
RAO	Radio Astronomical Observatory, Johannesburg, South Africa
RC	Comité Estatal de Normalizacion, Habana, Cuba

TABLE 1 - ATOMIC TIME, COLLABORATING LABORATORIES (CONT.)

RGO	Royal Greenwich Observatory, Cambridge, U.K.
ROA	Real Instituto y Observatorio de la Armada, San Fernando, España (formerly OMSF)
RSA	Consortium of laboratories in South Africa
SAAO	South African Astronomical Observatory, Cape Town, South Africa
SO	Shanghai Observatory, Shanghai, China
STA	Swedish Telecommunications Administration, Stockholm, Sweden
SU	Laboratoire d'état de l'étalon de temps et de fréquences, URSS
TAO	Tokyo Astronomical Observatory, Tokyo, Japan
TID	Tidbinbilla Deep Space Communications Center, Australia
TL	Telecommunication Laboratories, Taiwan, China
TP(1)	Ústav Radiotechniky a Elektroniky ČSAV, Praha, Československo Astronomický ústav ČSAV, Praha, Československo
TUG	Technische Universität Graz, Oesterreich
USNO	U.S. Naval Observatory, Washington D.C., USA
VSL	Van Swinden Laboratorium, Delft, Nederland
YUZM	Bureau Fédéral des Mesures et Métaux Précieux, Belgrade, Yougoslavie
ZIPE	Zentralinstitut Physik der Erde, Potsdam, Deutsche Demokratische Republik

(1) Both laboratories cooperate in the derivation of UTC(TP).

TABLE 2 - FREQUENCY OFFSETS AND STEP ADJUSTEMENTS OF UTC, UNTIL 1990 JUNE 30

Date (at 0 h UTC)		Offsets	Steps
1961	Jan. 1	-150×10^{-10}	
	Aug. 1	"	+0.050 s

1962	Jan. 1	-130×10^{-10}	
1963	Nov. 1	"	-0.100 s

1964	Jan. 1	-150×10^{-10}	
	Apr. 1	"	-0.100 s
	Sep. 1	"	-0.100 s
1965	Jan. 1	"	-0.100 s
	Mar. 1	"	-0.100 s
	Jul. 1	"	-0.100 s
	Sep. 1	"	-0.100 s

1966	Jan. 1	-300×10^{-10}	
1968	Feb. 1	"	+0.100 s

Date (at 0 h UTC)		Offsets	Steps
1972	Jan. 1	0	-0.107 7580 s
	Jul. 1	"	-1 s
1973	Jan. 1	"	-1 s
1974	Jan. 1	"	-1 s
1975	Jan. 1	"	-1 s
1976	Jan. 1	"	-1 s
1977	Jan. 1	"	-1 s
1978	Jan. 1	"	-1 s
1979	Jan. 1	"	-1 s
1980	Jan. 1	"	-1 s
1981	Jul. 1	"	-1 s
1982	Jul. 1	"	-1 s
1983	Jul. 1	"	-1 s
1985	Jul. 1	"	-1 s
1988	Jan. 1	"	-1 s
1990	Jan. 1	"	-1 s

TABLE 3 - RELATIONSHIP BETWEEN TAI AND UTC, UNTIL 1990 JUNE 30

Limits of validity (at 0 h UTC)			TAI - UTC (in seconds)
1961	Jan. 1	- 1961 Aug. 1	1.422 8180 + (MJD - 37300) x 0.001 296
	Aug. 1	- 1962 Jan. 1	1.372 8180 + " "
1962	Jan. 1	- 1963 Nov. 1	1.845 8580 + (MJD - 37665) x 0.001 1232
1963	Nov. 1	- 1964 Jan. 1	1.945 8580 + " "
1964	Jan. 1	Apr. 1	3.240 1300 + (MJD - 38761) x 0.001 296
	Apr. 1	Sep. 1	3.340 1300 + " "
	Sep. 1	- 1965 Jan. 1	3.440 1300 + " "
1965	Jan. 1	Mar. 1	3.540 1300 + " "
	Mar. 1	Jul. 1	3.640 1300 + " "
	Jul. 1	Sep. 1	3.740 1300 + " "
	Sep. 1	- 1966 Jan. 1	3.840 1300 + " "
1966	Jan. 1	- 1968 Feb. 1	4.313 1700 + (MJD - 39126) x 0.002 592
1968	Feb. 1	- 1972 Jan. 1	4.213 1700 + " "
1972	Jan. 1	- Jul. 1	10 (integral number of seconds)
	Jul. 1	- 1973 Jan. 1	11
1973	Jan. 1	- 1974 Jan. 1	12
1974	Jan. 1	- 1975 Jan. 1	13
1975	Jan. 1	- 1976 Jan. 1	14
1976	Jan. 1	- 1977 Jan. 1	15
1977	Jan. 1	- 1978 Jan. 1	16
1978	Jan. 1	- 1979 Jan. 1	17
1979	Jan. 1	- 1980 Jan. 1	18
1980	Jan. 1	- 1981 Jul. 1	19
1981	Jul. 1	- 1982 Jul. 1	20
1982	Jul. 1	- 1983 Jul. 1	21
1983	Jul. 1	- 1985 Jul. 1	22
1985	Jul. 1	- 1988 Jan. 1	23
1988	Jan. 1	- 1990 Jan. 1	24
1990	Jan. 1		25

TABLE 4 - LABORATORIES KEEPING AN INDEPENDENT LOCAL ATOMIC TIME

Laboratory (k)	Equipment in atomic standards (1)	Information on TA(k) - UTC(k): Interval of validity (in MJD at 0 h UTC)	Information on TA(k) - UTC(k): TA(k) - UTC(k) in s
AOS	1 Ind. Cs	47599-47619	TA(AOS)=UTC(AOS)
APL	1 Ind. Cs 4 H Masers	47379-47519 47529-47649 47659-47709 47719-47789 47799-	24.000 000 180 Data not reported 24.000 000 000 23.999 999 600 24.000 001 338
CH	13 Ind. Cs (2)	year 1989	TA(CH)-UTC(CH) is sent to BIPM
CRL	1 Lab. Cs 11 Ind. Cs 3 H Masers	year 1989	published in CRL Standard Frequency and Time Bulletin
CSAO	5 Ind. Cs 3 H Masers	year 1989	TA(CSAO)-UTC(CSAO) is published by the CSAO Time and Frequency Services Bulletin
DDR	2 Ind. Cs (3)	year 1989	TA(DDR)-UTC(ASMW) is sent to BIPM
F	22 Ind. Cs (4)	year 1989	TA(F)-UTC(OP) is published in bul-letin H by OP (LPTF)
JATC	1 Lab. Cs 14 Ind. Cs 6 H Masers (5)	year 1989	TA(JATC)-UTC(JATC) is sent to BIPM
NIM	3 Ind. Cs	year 1989	TA(NIM)-UTC(NIM) is sent to BIPM
NIST	1 Lab. Cs 19 Ind. Cs 1 H Maser (6)	year 1989	TA(NIST)-UTC(NIST) is published in the NIST T and F Bulletin

TABLE 4 - (CONT.)

Laboratory (k)	Equipment in atomic standards (1)	Information on TA(k) - UTC(k): Interval of validity (in MJD at 0 h UTC)	TA(k) - UTC(k) in s
NRC	1 2.1 m Lab. Cs 2 1 m Lab. Cs 1 Ind. Cs (7)	year 1989	23.999 968 931
PTB	2 Lab. Cs 7 Ind. Cs (8)	year 1989	24.000 363 400
RC	6 H Masers	year 1989	TA(RC)-UTC(RC) is sent to BIPM
SO	1 Lab. Cs 3 Ind. Cs 3 H Masers	year 1989	TA(SO)-UTC(SO) is published by the SO Atomic Time Bulletin
SU	2 Lab. Cs 6 H Clocks	year 1989	21.172 750 000
USNO	40 Ind. Cs 10 H Masers (4 VLG 11 B serial # 18,19,22,23 2 VLG 12 serial # 24,25 4 Sigma Tau, NAV1,NAV2,NAV3,NAV4) 3 Prototype Mercury Ion freq. Std. serial # 1,2,3 (9)	year 1989	A.1(MEAN)-UTC(USNO,MC) values are available upon request. (10)

NOTES OF TABLE 4

(1) Ind. Cs designates an industry made Cs standard; Lab. Cs a laboratory Cs standard and H Maser an Hydrogen Maser.

(2) The standards are located as follows (at the end of 1989).

Office Fédéral de Métrologie (Berne)	(OFM)	7 Cs
Observatoire de Neuchâtel (Neuchâtel)	(ON)	4 Cs
Direction Générale des PTT (Berne)	(PTT)	2 Cs

They are intercompared by LORAN-C (OFM-ON) and TV method (OFM-PTT) and linked to the foreign laboratories through the Swiss Federal Office of Metrology.

(3) The standards are located as follows : ASMW, 1 Cs ; ZIPE, 1 Cs.

(4) The standards are located as follows (at the end of 1989).

Centre Electronique de l'Armement (Rennes)	2 Cs
Centre National d'Etudes Spatiales (CNES)	2 Cs
Centre National d'Etudes des Télécommunications	3 Cs
Observatoire de la Côte d'Azur (OCA, formerly CERGA)	3 Cs
Electronique Serge Dassault (Trappes)	1 Cs
Hewlett-Packard (Orsay)	1 Cs
Observatoire de Paris : Laboratoire Primaire du Temps et des Fréquences (LPTF)	5 Cs
Observatoire de Besançon (OB)	2 Cs
Laboratoire de Physique et de Métrologie des Oscillateurs (Besançon) (LPMO)	1 Cs
Ecole Nationale Supérieure de Mécanique et des Microtechniques (Besançon) (ENSMM)	1 Cs
Société d'Etudes, Recherches et Constructions Electroniques (Carquefou) (SERCEL)	1 Cs

Links by GPS : OP-OB, OP-SERCEL, OP-OCA, OP-CNES (since March 1989)
Cable links : OB-LPMO, OB-ENSMM.
Other national links by the TV method
Link to foreign laboratories through OP(LPTF) by GPS (see Table 5).

(5) JATC. The standards are located in the following laboratories
Shaanxi Astronomical Observatory (CSAO)
Shanghai Astronomical Observatory (SO)
Beijing Astronomical Observatory
Wuhan Time Observatory
Beijing Institute of Radio Metrology and Measurement

(6) The laboratory primary standards control TA(NIST) via an accuracy algorithm. Six of the commercial standards provide the reference for WWV and WWVB and two for GOES Satellite time but do not contribute directly to TA(NIST); they are available for NIST time scales back-up and are compared to TA(NIST) to within 0.01 us. The hydrogen maser is passively operated.
An other independent local time is evaluated by a different algorithm. It is designated as AT1, but appears in BIPM publications as TA(NISA).

NOTES OF TABLE 4 (CONT.)

(7) The primary cesium clock, CsV, operated continuously during 1989 and was the source of UTC(NRC) until 1989 June 20, 19 h UTC. UTC(NRC) was then provided by NRC CsVIA. The relations between UTC(NRC) and these primary clocks, with PT designating proper time, are in microseconds:

From 1988 September 2 to 1989 June 20, 19 h UTC

UTC(NRC) = PT(NRC CsV) - (MJD-47409) x 0.00097 + 48.601

From 1989 June 20, 19 h UTC to 1990 January 1, 0 h UTC

UTC(NRC) - PT(NRC Cs VIA) - (MJD-47679) x 0.017387 +35.245

(8) The two Lab. Cs are functionning continuously (primary clocks). TA(PTB) and UTC(PTB) are derived directly from a local oscillator monitored by the primary clock CS1.
MEZ(D) = UTC(PTB) + 1 h or MESZ(D) = UTC(PTB) + 2 h (summer time) is the legal time of the Federal Republic of Germany, which is disseminated by DCF77.
Two Ind. Cs are located at the transmitter station Mainflingen and provide the DCF77 steering signal.

(9) The time scales UTC(USNO) and TA(USNO) depend on nominally 20 Cs selected clocks (selected on the basis of observed 5-day stability).

(10) TA(USNO) is designated by A.1 (MEAN) by USNO.

TABLE 5 - EQUIPMENT AND LINKS OF THE COLLABORATING LABORATORIES IN 1989

Laboratory (k)	Equipment (1)	Source of UTC(k)	LORAN-C reception (2)	Television link with	GPS reception
AOS	1 Ind. Cs	1 Cs		PKNM, ZIPE	
APL	see Table 4	1 H Maser			*
ASMW	1 Ind. Cs	1 Cs + microstepper	7970-W	ZIPE, TP, PTB	
ATC	7 Ind. Cs	1 Cs + microstepper		other lab. in Australia	*
BEV	1 Ind. Cs	1 Cs	7970-W 7990-M 7990-X 7990-Y	OMH, TUG, lab. in Czechoslovakia	
CAO	2 Ind. Cs	1 Cs	7990-M 7990-X 7990-Z	IEN, other lab. in Italy	
CH	see Table 4	all the Cs	7970-W 7990-Z	PTT	*
CRL	see Table 4	6 Cs	9970-M	NRLM, TAO	*
CSAO	see Table 4	all the Cs	9970-Y	lab. in China	
DPT	1 Ind. Cs	1 Cs			*
FTZ	7 Ind. Cs	1 Cs	7970-W		
IEN	5 Ind. Cs	1 Cs + microstepper	7990-Z	CAO, other lab. in Italy	*
IFAG	4 Ind. Cs 2 H Masers	1 Cs + microstepper	7970-W		*
IGMA	4 Ind. Cs	1 Cs + microstepper		ONBA, other lab. in Argentina	*
INPL	3 Ind. Cs	1 Cs			*
JATC	see Table 4	1 Cs + microstepper	9970-Y		

TABLE 5 - (CONT.)

Laboratory (k)	Equipment (1)	Source of UTC(k)	LORAN-C reception (2)	Television link with	GPS reception
KSRI	4 Ind. Cs	1 Cs	9970-Y		*
NAOM	4 Ind. Cs	1 Cs	9970-M 9970-X		* (since March 1989)
NIM	see Table 4	1 Cs + microstepper	9970-Y	lab. in China	*
NIST	see Table 4	11 Cs 1 Lab. Cs 1 H Maser	9940-M 9960-Z		*
NML	3 Ind. Cs 2 H masers	all the Cs		other lab. in Sydney region	*
NPL	7 Ind. Cs	1 Cs + microstepper	7970-W	transmitting station at Rugby	*
NPLI	5 Ind. Cs	1 Cs			*
NRC	see Table 4	47406 to 47679 CsV 47679-CsVIA	9960-M		*
NRLM	5 Ind. Cs 2 Lab. Cs	1 Cs	9970-M 9970-X	CRL, TAO	* (since Feb. 1989)
OMH	1 Ind. Cs	1 Cs		BEV, SU, TP	
ONBA	2 Ind. Cs	2 Cs		IGMA other lab. in Argentina	
ONRJ	5 Ind. Cs	5 Cs		other lab. in Brasil	*
OP	5 Ind. Cs	1 Cs	7970-W 7990-Z 8940-M	18 lab. in France.	*
ORB	3 Ind. Cs	1 Cs	7970-W		*

TABLE 5 - (CONT.)

Laboratory (k)	Equipment (1)	Source of UTC(k)	LORAN-C reception (2)	Television link with	GPS reception
ORR	5 Ind. Cs	all the Cs		other lab. in Australia	*
PKNM	2 Ind. Cs	1 Cs + microstepper	7970-W (3)	AOS	
PEL	3 Ind. Cs	1 Cs		other lab. in New Zeland	
PTB	see Table 4	Ind. Cs + microstepper steered by PTB primary st.	7970-W	ASMW, TP, ZIPE and other lab.	*
RAO	1 H Maser				*
RC	see Table 4	4 H Masers	7980-M 7980-Y		
ROA	6 Ind. Cs	all the Cs	7990-Z		*
SAAO	1 Ind. Cs	1 Cs			*
SO	see Table 4	1 Cs + microstepper	9970-Y	lab. in China	
STA	3 Ind. Cs	1 Cs	7970-W	other lab. in Sweden	*
SU	see Table 4	2 Lab. Cs 6 H Clocks	7970-W 9970-X	TP, OMH	
TAO	8 Ind. Cs	1 Cs + microstepper	9970-M 9970-Y	CRL, NAOM NRLM	*
TL	5 Ind. Cs	1 Cs + microstepper	9970-Y		*
TP	2 Ind. Cs	1 Cs + microstepper	7970-W	PTB, SU, ZIPE, ASMW, OMH	
TUG	3 Ind. Cs	1 Cs	7970-W 7990-M	BEV	*
USNO	see Table 4	Master clock is H Maser + freq. synthe- sizer steered to UTC(USNO) (see table 4)	(4)		* (5)

TABLE 5 - (CONT.)

Laboratory (k)	Equipment (1)	Source of UTC(k)	LORAN-C reception (2)	Television link with	GPS reception
VSL	4 Ind. Cs	1 Cs + microstepper	7970-M 7970-W 9980-X	11 Lab. in Netherlands	*
YUZM	1 Ind. Cs	Cs	7990-M		
ZIPE	1 Ind. Cs	1 Cs + microstepper	7970-W	AOS, ASMW, TP, PTB	

NOTES OF TABLE 5

(1) Ind. Cs designates an industry made Cs standard;
Lab. Cs a laboratory Cs standard, H. Maser an Hydrogen Maser, and Rb designates a Rubidium standard.

(2) LORAN-C stations :

7970-M	Norwegian Sea chain,	Ejde
7970-W	" "	Sylt
7980-M	Southeast USA chain	Malone
7980-Y	" "	Jupiter
7990-M	Mediterranean chain,	Simeri Crichi
7990-X	" "	Lampedusa
7990-Y	" "	Kargabarun
7990-Z	" "	Estartit
8940-M	French chain,	Lessay
9940-M	West Coast chain,	Fallon
9960-M	Northeast Coast chain,	Seneca
9960-X	" "	Nantucket
9960-Z	" "	Dana
9970-M	Northwest Pacific chain,	Iwo Jima
9970-X	" "	Hokkaido
9970-Y	" "	Gesashi
9980-M	North Atlantic chain,	Angissog
9980-X	" "	Ejde

NOTES OF TABLE 5 (CONT.)

(3) Reception of the Soviet Union LORAN chain 8000.

(4) The daily time differences (published weekly, Series 4 of USNO) gives the values of UTC(USNO MC) - transmitting station for :

the LORAN-C chains,
the Washington D.C. TV Station WTTG,
the GPS satellite system.

These data are also available via the Automated Data Service (ADS) and the General Electric Mark 3 international computer network (RC28 catalog).
The ADS may be accessed on :

BELL 103/212 (300 or 1200 Baud)	202-653-1079,
CCITT V.21 (300 Baud)	202-653-1095,
CCITT V.22/V.22 bis (1200 or 2400 Baud)	202-653-1783.

(5) Two-way satellite time transfer also operates between USNO and NIST.

* Laboratories with GPS receiver equipment.

TABLE 6 - TIME COMPARISONS BETWEEN LABORATORIES IN 1989

A - CLOCK TRANSPORTATION

Unless otherwise stated, the transportation was carried out by the first mentioned laboratory.

DATE 1989		MJD	TIME COMPARISONS (unit : 1 microsecond)		UNCERT.	SOURCE	
MAR	5	47590.58	UTC(SU) - UTC(NPL) =	-15.56	0.03	SU	telex
MAY	15	47661.70	UTC(OMH) - UTC(TP) =	8.48		OMH	letter
MAY	22	47668.05	UTC(TAO) - UTC(CRL) =	1.798	0.005	TAO	message
JUL	25	47732.50	UTC(SU) - UTC(STA) =	12.55	0.02	SU	telex
OCT	23	47822.53	UTC(TP) - UTC(CH) =	-1.48	0.1	TP	telex
OCT	26	47825.58	UTC(TP) - UTC(PTB) =	2.91	0.1	TP	telex
OCT	27	47826.47	UTC(TP) - UTC(ZIPE) =	-1.53	0.05	TP	telex
OCT	27	47826.51	UTC(TP) - UTC(ASMW) =	-0.99	0.05	TP	telex
NOV	15	47845.00	UTC(SU) - UTC(ASMW) =	-12.12	0.01	SU	telex
NOV	30	47860.06	UTC(SU) - UTC(PKNM) =	-12.00	0.05	SU	telex
DEC	13	47873.44	UTC(SU) - UTC(OMH) =	-20.991	0.03	SU	telex

B - GPS TIME COMPARISONS WITH DIFFERENTIAL CALIBRATION OF RECEIVER DELAYS

Unless otherwise stated, under the heading SOURCE is designated the laboratory which has organized the measurement of delays.

DATE	MJD	TIME COMPARISONS	UNCERT.	SOURCE
1989		(unit : 1 microsecond)		

NONE

TABLE 7 - INDEPENDENT LOCAL ATOMIC TIME SCALES

TA(k) DENOTES THE ATOMIC TIME OF THE LABORATORY k

Unit is one microsecond

DATE 1989	MJD	TAI - TA(k) AOS	APL	AUS *	CH	CRL
JAN 3	47529	-	-	-18.000	-54.175	-3.273
JAN 13	47539	-	-	-18.080	-54.370	-3.239
JAN 23	47549	-	-	-18.339	-54.557	-3.179
FEB 2	47559	-	-	-18.381	-54.709	-3.114
FEB 12	47569	-	-	-18.578	-54.888	-3.066
FEB 22	47579	-	-	-18.648	-55.070	-3.007
MAR 4	47589	-	-	-18.816	-55.256	-2.972
MAR 14	47599	-5.83	-	-18.970	-55.457	-2.956
MAR 24	47609	-6.37	-	-19.128	-55.666	-2.944
APR 3	47619	-5.39	-	-19.265	-55.867	-2.960
APR 13	47629	-	-	-19.430	-56.101	-2.943
APR 23	47639	-	-	-19.654	-56.352	-2.943
MAY 3	47649	-	-	-19.810	-56.610	-2.932
MAY 13	47659	-	-0.821	-20.020	-56.866	-2.888
MAY 23	47669	-	-0.842	-20.210	-57.124	-2.851
JUN 2	47679	-	-0.790	-20.440	-57.394	-2.849
JUN 12	47689	-	-0.799	-20.678	-57.647	-2.799
JUN 22	47699	-	-	-20.881	-57.873	-2.783
JUL 2	47709	-	-	-21.143	-58.099	-2.764
JUL 12	47719	-	-1.111	-21.413	-58.307	-2.739
JUL 22	47729	-	-1.350	-21.707	-58.547	-2.709
AUG 1	47739	-	-1.422	-22.025	-58.785	-2.665
AUG 11	47749	-	-1.437	-22.325	-59.056	-2.607
AUG 21	47759	-	-1.646	-22.557	-59.314	-2.537
AUG 31	47769	-	-1.634	-22.841	-59.571	-2.461
SEP 10	47779	-	-1.708	-23.082	-59.834	-2.371
SEP 20	47789	-	-1.644	-23.305	-60.100	-2.333
SEP 30	47799	-	-	-23.567	-60.347	-2.284
OCT 10	47809	-	-1.555	-23.803	-60.565	-2.229
OCT 20	47819	-	-1.506	-24.090	-60.818	-2.214
OCT 30	47829	-	-1.458	-24.330	-61.059	-2.185
NOV 9	47839	-	-1.408	-24.490	-61.290	-2.151
NOV 19	47849	-	-1.364	-24.734	-61.531	-2.131
NOV 29	47859	-	-1.369	-24.997	-61.779	-2.126
DEC 9	47869	-	-1.367	-25.151	-61.997	-2.096
DEC 19	47879	-	-1.316	-25.316	-62.209	-2.065
DEC 29	47889	-	-1.258	-25.516	-62.438	-2.036

* The time scale previously designated as UTC(AUS) became TA(AUS) on 1st of January 1989, without time or frequency step.

TABLE 7 - (CONT.)

Unit is one microsecond

DATE 1989		MJD	TAI - TA(k) CSAO	DDR	F	JATC	NIM
JAN	3	47529	40.27	-29.59	64.724	1.22	-9.83
JAN	13	47539	40.30	-29.47	65.105	1.18	-9.75
JAN	23	47549	40.14	-29.31	65.478	1.05	-9.77
FEB	2	47559	40.10	-29.11	65.848	0.84	-9.89
FEB	12	47569	39.85	-28.98	66.227	0.60	-10.30
FEB	22	47579	39.71	-28.82	66.578	0.37	-10.45
MAR	4	47589	39.67	-28.59	66.910	0.26	-10.50
MAR	14	47599	39.55	-28.47	67.255	0.13	-10.66
MAR	24	47609	39.54	-28.41	67.582	0.16	-10.74
APR	3	47619	39.39	-28.28	67.908	0.00	-10.85
APR	13	47629	39.33	-28.11	68.256	-0.04	-10.89
APR	23	47639	39.23	-27.98	68.577	-0.09	-10.89
MAY	3	47649	39.01	-27.89	68.904	-0.30	-11.08
MAY	13	47659	38.72	-27.91	69.231	-1.18	-11.09
MAY	23	47669	38.56	-27.90	69.551	-0.67	-11.24
JUN	2	47679	38.58	-27.90	69.880	-0.68	-11.46
JUN	12	47689	38.74	-27.96	70.222	-0.73	-11.44
JUN	22	47699	38.80	-28.00	70.518	-0.78	-11.38
JUL	2	47709	38.54	-28.04	70.859	-0.91	-11.54
JUL	12	47719	38.50	-28.19	71.198	-0.91	-11.68
JUL	22	47729	38.55	-28.28	71.506	-0.98	-11.75
AUG	1	47739	38.46	-28.34	71.845	-0.99	-11.24
AUG	11	47749	38.04	-28.44	72.178	-1.20	-10.88
AUG	21	47759	38.03	-28.51	72.506	-1.30	-10.09
AUG	31	47769	37.92	-28.55	72.868	-1.28	-9.48
SEP	10	47779	37.75	-28.57	73.194	-1.24	-9.37
SEP	20	47789	37.63	-28.57	73.500	-1.27	-9.31
SEP	30	47799	37.61	-28.70	73.807	-1.25	-9.48
OCT	10	47809	37.59	-28.73	74.107	-1.22	-
OCT	20	47819	37.42	-28.74	74.396	-1.37	-
OCT	30	47829	37.14	-28.73	74.690	-1.41	-
NOV	9	47839	36.76	-28.76	74.990	-1.37	-
NOV	19	47849	36.53	-28.67	75.305	-1.34	-
NOV	29	47859	36.28	-28.48	75.597	-1.50	-
DEC	9	47869	35.95	-28.28	75.939	-1.42	-10.36
DEC	19	47879	35.62	-28.02	76.252	-1.35	-10.41
DEC	29	47889	35.25	-27.91	76.562	-1.41	-10.47

TABLE 7 - (CONT.)

Unit is one microsecond

DATE 1989	MJD	TAI - TA(k) NISA *	NIST	NRC	PTB
JAN 3	47529	-45053.148	-45119.514	18.089	-359.296
JAN 13	47539	-45053.373	-45119.923	17.885	-359.318
JAN 23	47549	-45053.591	-45120.325	17.737	-359.319
FEB 2	47559	-45053.823	-45120.740	17.695	-359.260
FEB 12	47569	-45054.071	-45121.165	17.648	-359.243
FEB 22	47579	-45054.320	-45121.605	17.619	-359.205
MAR 4	47589	-45054.546	-45122.038	17.603	-359.168
MAR 14	47599	-45054.785	-45122.475	17.614	-359.120
MAR 24	47609	-45055.019	-45122.903	17.592	-359.117
APR 3	47619	-45055.259	-45123.324	17.559	-359.106
APR 13	47629	-45055.501	-45123.752	17.528	-359.106
APR 23	47639	-45055.780	-45124.208	17.399	-359.121
MAY 3	47649	-45056.053	-45124.649	17.447	-359.119
MAY 13	47659	-45056.306	-45125.076	17.388	-359.172
MAY 23	47669	-45056.561	-45125.508	17.295	-359.176
JUN 2	47679	-45056.814	-45125.943	17.190	-359.182
JUN 12	47689	-45057.054	-45126.357	17.152	-359.209
JUN 22	47699	-45057.301	-45126.790	17.090	-359.236
JUL 2	47709	-45057.530	-45127.208	17.029	-359.241
JUL 12	47719	-45057.765	-45127.636	16.941	-359.260
JUL 22	47729	-45058.014	-45128.073	16.817	-359.307
AUG 1	47739	-45058.274	-45128.517	16.684	-359.313
AUG 11	47749	-45058.505	-45128.949	16.565	-359.382
AUG 21	47759	-45058.735	-45129.388	16.443	-359.393
AUG 31	47769	-45058.952	-45129.814	16.320	-359.378
SEP 10	47779	-45059.182	-45130.240	16.171	-359.384
SEP 20	47789	-45059.423	-45130.688	16.009	-359.424
SEP 30	47799	-45059.671	-45131.158	15.872	-359.461
OCT 10	47809	-45059.879	-45131.599	15.750	-359.493
OCT 20	47819	-45060.108	-45132.057	15.629	-359.529
OCT 30	47829	-45060.349	-45132.511	15.485	-359.552
NOV 9	47839	-45060.576	-45132.954	15.390	-359.580
NOV 19	47849	-45060.777	-45133.418	15.312	-359.580
NOV 29	47859	-45061.009	-45133.923	15.242	-359.571
DEC 9	47869	-45061.210	-45134.408	15.238	-359.561
DEC 19	47879	-45061.402	-45134.885	15.265	-359.584
DEC 29	47889	-45061.622	-45135.380	15.279	-359.615

* TA(NISA) designates the scale AT1 of NIST .

TABLE 7 - (CONT.)

Unit is one microsecond

DATE 1989	MJD	TAI - TA(k) RC	SO	SU *	USNO
JAN 3	47529	17999769.59	-44.73	2827266.66	-34571.330
JAN 13	47539	17999768.91	-44.55	2827266.66	-34571.938
JAN 23	47549	17999768.16	-44.51	2827266.48	-34572.537
FEB 2	47559	17999767.39	-44.36	2827266.12	-34573.148
FEB 12	47569	17999766.63	-44.43	2827265.99	-34573.731
FEB 22	47579	17999766.06	-44.42	2827265.86	-34574.285
MAR 4	47589	17999765.12	-44.37	2827265.71	-34574.846
MAR 14	47599	17999764.63	-44.46	2827265.82	-34575.436
MAR 24	47609	17999764.00	-44.41	2827265.78	-34576.059
APR 3	47619	17999763.38	-44.45	2827265.59	-34576.650
APR 13	47629	17999762.56	-44.39	2827265.46	-34577.250
APR 23	47639	17999761.90	-44.32	2827265.24	-34577.795
MAY 3	47649	17999761.08	-44.39	2827265.17	-34578.348
MAY 13	47659	17999760.21	-44.57	2827264.93	-34578.916
MAY 23	47669	17999759.47	-44.67	2827264.77	-34579.532
JUN 2	47679	17999758.64	-44.73	2827264.52	-34580.100
JUN 12	47689	17999757.81	-44.68	2827264.50	-34580.661
JUN 22	47699	17999757.01	-44.61	2827264.28	-34581.232
JUL 2	47709	17999756.13	-44.58	2827264.06	-34581.781
JUL 12	47719	17999755.18	-44.52	2827263.93	-34582.345
JUL 22	47729	17999754.40	-44.57	2827263.92	-34582.894
AUG 1	47739	17999753.32	-44.57	2827263.50	-34583.467
AUG 11	47749	17999752.38	-44.68	2827263.28	-34583.999
AUG 21	47759	17999751.52	-44.62	2827263.05	-34584.548
AUG 31	47769	17999750.71	-44.61	2827262.92	-34585.080
SEP 10	47779	17999749.93	-44.60	2827262.80	-34585.653
SEP 20	47789	17999749.13	-44.53	2827262.68	-34586.231
SEP 30	47799	17999748.32	-44.45	2827262.55	-34586.757
OCT 10	47809	17999747.40	-44.28	2827262.43	-34587.305
OCT 20	47819	17999746.62	-44.32	2827262.31	-34587.774
OCT 30	47829	17999745.90	-44.24	2827262.18	-34588.290
NOV 9	47839	17999744.84	-44.16	2827262.06	-34588.844
NOV 19	47849	17999743.86	-44.04	2827261.94	-34589.456
NOV 29	47859	17999743.16	-44.04	2827261.75	-34589.983
DEC 9	47869	17999742.22	-43.96	2827261.75	-34590.629
DEC 19	47879	17999741.39	-43.85	2827261.62	-34591.321
DEC 29	47889	17999740.80	-43.84	2827261.29	-34591.964

* From MJD = 47769 to MJD = 47859, interpolated values using clock transportations reported in Table 6.

TABLE 8 - PRIMARY STANDARDS USED AS CLOCKS

Unit is one microsecond

TAI-LAB.STD.

DATE 1989	MJD	PTB (1)		NRC (2)		
		CS1	CS2	CsV	CsVI A	CsVI C
JAN 3	47529	4.100	2.006	35.505	24.772	27.398
JAN 13	47539	4.088	1.990	35.291	24.444	27.265
JAN 23	47549	4.101	1.998	35.134	24.214	27.074
FEB 2	47559	4.134	1.977	35.082	23.992	26.907
FEB 12	47569	4.178	1.969	35.025	23.773	26.696
FEB 22	47579	4.211	1.954	34.986	23.543	26.494
MAR 4	47589	4.251	1.934	34.961	23.318	26.297
MAR 14	47599	4.280	1.916	34.962	23.090	26.355
MAR 24	47609	4.286	1.892	34.930	22.897	26.578
APR 3	47619	4.307	1.878	34.887	22.700	26.810
APR 13	47629	4.299	1.845	34.847	22.504	26.544
APR 23	47639	4.280	1.799	34.709	22.280	26.994
MAY 3	47649	4.264	1.766	34.747	22.066	27.003
MAY 13	47659	4.249	1.730	34.680	21.827	26.886
MAY 23	47669	4.223	1.685	34.577	21.586	26.711
JUN 2	47679	4.199	1.656	34.460	21.366	26.489
JUN 12	47689	4.197	1.623	34.302	21.155	26.251
JUN 22	47699	4.180	1.586	34.127	20.918	26.122
JUL 2	47709	4.144	1.539	33.916	20.684	25.879
JUL 12	47719	4.125	1.498	33.569	20.422	25.600
JUL 22	47729	4.094	1.442	33.170	20.124	25.335
AUG 1	47739	4.074	1.389	32.821	19.817	25.227
AUG 11	47749	4.024	1.335	32.496	19.524	25.233
AUG 21	47759	4.014	1.293	32.128	19.228	25.236
AUG 31	47769	4.013	1.286	31.887	18.931	25.258
SEP 10	47779	3.999	1.249	31.603	18.608	25.281
SEP 20	47789	3.968	1.197	31.302	18.272	25.251
SEP 30	47799	3.938	1.154	30.927	17.961	24.968
OCT 10	47809	3.923	1.158	30.689	17.666	24.667
OCT 20	47819	3.879	1.106	30.454	17.371	24.377
OCT 30	47829	3.855	1.061	30.211	17.053	24.133
NOV 9	47839	3.839	1.044	29.950	16.784	23.893
NOV 19	47849	3.857	1.018	29.656	16.532	23.694
NOV 29	47859	3.839	0.958	29.320	16.289	23.536
DEC 9	47869	3.820	0.935	29.011	16.110	23.504
DEC 19	47879	3.819	0.921	28.706	15.964	23.542
DEC 29	47889	3.798	0.898	28.397	15.804	23.569

TABLE 8 - (CONT.)

NOTES

(1) The time scales under the headlines PTB CS1, CS2 are coordinate time scales at sea level derived from the scales of proper time produced by standards CS1 and CS2 of PTB. The gravitational correction is -0.00066μs/d .

(2) The time scales under the headlines NRC Cs V, Cs VI A, Cs VI C, are the scales of proper time PT(NRC Cs V), PT(NRC Cs VI A), PT(NRC Cs VI C), produced directly by primary frequency standards Cs V, Cs VI A, Cs VI C, of NRC used as clocks. The gravitational frequency correction to these time scales of proper time to obtain coordinate times at sea level is -0.00097μs/d .

TABLE 9 - COORDINATED UNIVERSAL TIME

UTC(k) DENOTES THE APPROXIMATION TO UTC KEPT BY THE LABORATORY k

Unit is one microsecond

DATE 1989	MJD	UTC - UTC(k) AOS (1)	APL (2)	ASMW	AUS (3)	BEV (4)	CAO
JAN 3	47529	-	-	0.34	-1.343	-4.67	4.87
JAN 13	47539	-	-	0.20	-1.298	-5.26	5.16
JAN 23	47549	-	-	0.07	-1.242	-5.75	5.17
FEB 2	47559	-	-	0.01	-1.189	-6.32	5.45
FEB 12	47569	-	-	-0.10	-1.151	-6.91	5.72
FEB 22	47579	-	-	-0.18	-1.109	-7.48	5.96
MAR 4	47589	-	-	-0.10	-1.068	-8.03	6.22
MAR 14	47599	-5.83	-	-0.03	-1.035	-8.76	6.42
MAR 24	47609	-6.37	-	-0.03	-1.013	-9.43	6.75
APR 3	47619	-5.39	-	0.06	-0.989	-9.97	7.03
APR 13	47629	-5.17	-	0.24	-0.960	-10.44	7.29
APR 23	47639	-5.44	-	0.34	-0.953	-11.56	7.52
MAY 3	47649	-5.44	-	0.38	-0.941	-12.26	7.72
MAY 13	47659	-	-0.821	0.26	-0.931	6.99	8.00
MAY 23	47669	2.38	-0.842	0.17	-0.933	6.23	8.23
JUN 2	47679	3.98	-0.790	0.09	-0.940	5.36	8.54
JUN 12	47689	5.21	-0.799	-0.10	-0.938	4.52	8.81
JUN 22	47699	6.56	-	-0.17	-0.951	3.56	9.01
JUL 2	47709	7.94	-	-0.22	-0.958	2.55	9.14
JUL 12	47719	9.21	-1.511	-0.42	-0.964	1.31	9.33
JUL 22	47729	10.74	-1.750	-0.41	-0.976	0.83	9.45
AUG 1	47739	12.18	-1.822	-0.31	-0.994	-0.67	9.49
AUG 11	47749	13.68	-1.837	-0.25	-1.000	-1.65	9.59
AUG 21	47759	14.39	-2.046	-0.25	-0.991	-2.98	9.73
AUG 31	47769	16.13	-2.034	-0.19	-0.972	-4.16	9.79
SEP 10	47779	17.37	-2.108	0.01	-0.975	-5.00	9.82
SEP 20	47789	-11.55	-2.044	0.20	-0.972	-6.28	9.95
SEP 30	47799	-11.36	-	0.16	-0.943	-7.32	10.14
OCT 10	47809	-10.76	-0.217	0.09	-0.879	-8.13	10.14
OCT 20	47819	-10.16	-0.168	-0.04	-0.822	-	10.10
OCT 30	47829	-9.42	-0.120	-0.13	-0.785	-	10.11
NOV 9	47839	-8.36	-0.070	-0.22	-0.771	-	-
NOV 19	47849	-7.77	-0.026	-0.08	-0.754	-	-
NOV 29	47859	-6.92	-0.031	0.25	-0.767	-	12.25
DEC 9	47869	-5.51	-0.029	0.44	-0.872	-	12.46
DEC 19	47879	-4.13	0.022	0.46	-0.936	-	12.52
DEC 29	47889	-2.98	0.080	0.25	-1.010	-	12.73

TABLE 9 - (CONT.)

Unit is one microsecond

DATE 1989	MJD	UTC - UTC(k) CH	CRL	CSAO	DPT	FTZ	IEN (5)
JAN 3	47529	0.722	-1.693	1.29	-	17.58	0.150
JAN 13	47539	0.710	-1.659	1.32	-	17.51	-0.305
JAN 23	47549	0.706	-1.609	1.16	-	17.45	-0.733
FEB 2	47559	0.736	-1.554	1.12	-	17.44	-0.762
FEB 12	47569	0.739	-1.506	0.87	-	17.32	-0.795
FEB 22	47579	0.740	-1.457	0.73	-	17.26	-0.827
MAR 4	47589	0.737	-1.422	0.69	-	17.24	-0.873
MAR 14	47599	0.718	-1.426	0.57	-	17.23	-0.958
MAR 24	47609	0.692	-1.434	0.56	-	17.22	-0.901
APR 3	47619	0.673	-1.460	0.41	-	17.20	-0.847
APR 13	47629	0.622	-1.463	0.35	-	17.19	-0.817
APR 23	47639	0.553	-1.483	0.24	-	17.18	-0.767
MAY 3	47649	0.477	-1.482	0.03	-	17.16	-0.731
MAY 13	47659	0.404	-1.448	-0.26	-	17.16	-0.703
MAY 23	47669	0.329	-1.421	-0.42	-	17.13	-0.669
JUN 2	47679	0.242	-1.439	-0.40	-	17.11	-0.608
JUN 12	47689	0.171	-1.399	-0.24	-	17.09	-0.569
JUN 22	47699	0.127	-1.393	-0.19	-	17.11	-0.532
JUL 2	47709	0.084	-1.384	-0.44	-14.182	17.10	-0.488
JUL 12	47719	0.059	-1.369	-0.49	-14.312	17.11	-0.437
JUL 22	47729	0.001	-1.359	-0.43	-14.452	17.16	-0.378
AUG 1	47739	-0.054	-1.324	-0.52	-14.481	17.25	-0.322
AUG 11	47749	-0.142	-1.276	-0.94	-14.605	17.21	-0.101
AUG 21	47759	-0.217	-1.215	-0.95	-14.776	17.05	0.125
AUG 31	47769	-0.293	-1.148	-1.06	-14.871	16.83	0.375
SEP 10	47779	-0.376	-1.065	-1.24	-14.984	16.77	0.356
SEP 20	47789	-0.463	-1.037	-1.35	-15.114	16.75	0.302
SEP 30	47799	-0.537	-1.005	-1.37	-15.246	16.71	0.275
OCT 10	47809	-0.585	-0.958	-1.39	-15.418	16.60	0.237
OCT 20	47819	-0.668	-0.948	-1.56	-15.623	16.56	0.178
OCT 30	47829	-0.739	-0.925	-1.84	-15.886	16.55	0.129
NOV 9	47839	-0.795	-0.909	-2.14	-16.178	16.54	0.058
NOV 19	47849	-0.861	-0.890	-2.27	-16.501	16.45	-0.016
NOV 29	47859	-0.929	-0.888	-2.42	-16.750	16.47	-0.106
DEC 9	47869	-0.964	-0.868	-2.65	-17.049	16.42	-0.157
DEC 19	47879	-0.992	-0.836	-2.88	-17.354	16.38	-0.227
DEC 29	47889	-1.040	-0.820	-3.15	-17.627	16.41	-0.303

TABLE 9 - (CONT.)

Unit is one microsecond

DATE 1989	MJD	UTC - UTC(k) IFAG (6)	IGMA	INPL	INTI	JATC	KSRI (7)
JAN 3	47529	0.069	-	94.804	-	3.00	-19.386
JAN 13	47539	0.294	-	96.176	-	2.85	-19.693
JAN 23	47549	0.554	-	97.540	-	2.48	-19.985
FEB 2	47559	-1.067	-	98.991	-	2.02	-20.533
FEB 12	47569	-0.791	-	100.530	-	1.49	-21.248
FEB 22	47579	-0.509	-	102.141	-	0.98	-21.919
MAR 4	47589	-0.290	-	103.759	-	0.57	-22.763
MAR 14	47599	-0.452	-	105.172	-	0.14	-23.423
MAR 24	47609	-0.424	-	106.629	-	-0.20	-24.033
APR 3	47619	-0.681	-	108.099	-	-0.63	-24.578
APR 13	47629	-0.959	-	109.539	-	-1.04	-25.077
APR 23	47639	-0.881	-	110.978	-	-1.45	-25.601
MAY 3	47649	-1.097	-	112.394	-	-2.09	-26.103
MAY 13	47659	-1.188	-	113.922	-	-3.15	-26.592
MAY 23	47669	-1.287	-	115.530	-	-2.76	-11.938
JUN 2	47679	-1.199	-	117.156	-	-2.73	-11.087
JUN 12	47689	-1.449	-	119.204	-	-2.88	-10.523
JUN 22	47699	-1.774	-	121.273	-	-3.10	-10.438
JUL 2	47709	-1.880	-	122.983	-	-3.49	-10.246
JUL 12	47719	-1.945	-	124.335	-	-3.75	-10.093
JUL 22	47729	-2.249	-	125.697	-	-3.95	-9.891
AUG 1	47739	-2.571	-	127.058	-	-4.14	-9.843
AUG 11	47749	-2.440	-	128.411	-	-4.90	-9.825
AUG 21	47759	-2.239	-	129.776	-	-5.20	-9.674
AUG 31	47769	-2.042	-	131.193	-	-5.56	-9.625
SEP 10	47779	-1.751	-	132.481	-	-5.97	-9.464
SEP 20	47789	-1.517	-	133.808	-	-6.34	-9.390
SEP 30	47799	-1.192	-	135.125	-	-6.68	-9.308
OCT 10	47809	-0.914	-	136.481	-	-6.99	-9.246
OCT 20	47819	-0.655	-	137.797	-	-7.34	-9.067
OCT 30	47829	-0.309	-	139.133	-	-7.86	-8.984
NOV 9	47839	-0.202	-	140.493	-	-8.40	-8.872
NOV 19	47849	0.108	-	141.825	-	-9.00	-8.876
NOV 29	47859	0.322	-	143.172	-	-9.44	-8.688
DEC 9	47869	0.566	-	144.682	-	-9.76	-8.596
DEC 19	47879	0.764	-	146.117	-	-10.07	-8.484
DEC 29	47889	0.892	-	147.607	-	-10.33	-8.231

TABLE 9 - (CONT.)

Unit is one microsecond

DATE 1989	MJD	UTC - UTC(k) NAOM (8)	NIM	NIST	NPL	NPLI	NRC
JAN 3	47529	-34.81	7.65	-0.110	2.407	-11.430	-12.980
JAN 13	47539	-34.89	7.52	-0.127	2.114	-11.197	-13.184
JAN 23	47549	-35.02	7.41	-0.138	1.855	-11.159	-13.332
FEB 2	47559	-35.04	7.19	-0.163	1.532	-11.037	-13.374
FEB 12	47569	-35.09	6.82	-0.214	1.205	-10.907	-13.421
FEB 22	47579	-35.14	6.47	-0.265	0.833	-10.864	-13.450
MAR 4	47589	-35.657	6.34	-0.290	0.479	-11.080	-13.466
MAR 14	47599	-35.741	6.21	-0.319	0.243	-11.203	-13.455
MAR 24	47609	-35.692	6.15	-0.343	0.110	-11.322	-13.477
APR 3	47619	-35.689	5.94	-0.370	0.000	-11.459	-13.510
APR 13	47629	-35.618	5.95	-0.387	-0.150	-11.539	-13.541
APR 23	47639	-35.634	6.00	-0.441	-0.347	-11.597	-13.670
MAY 3	47649	-35.673	5.90	-0.486	-0.575	-11.602	-13.622
MAY 13	47659	-35.708	5.97	-0.499	-0.798	-11.684	-13.681
MAY 23	47669	-35.664	5.90	-0.514	-1.040	-11.795	-13.774
JUN 2	47679	-35.657	5.71	-0.526	-1.063	-11.958	-13.879
JUN 12	47689	-35.640	5.71	-0.516	-1.046	-12.202	-13.917
JUN 22	47699	-35.641	5.73	-0.513	-1.029	-12.550	-13.979
JUL 2	47709	-35.564	5.54	-0.491	-1.006	-12.882	-14.040
JUL 12	47719	-35.622	5.36	-0.466	-0.978	-13.222	-14.128
JUL 22	47729	-35.705	5.36	-0.455	-0.927	-13.517	-14.252
AUG 1	47739	-35.609	6.46	-0.455	-0.946	-13.807	-14.385
AUG 11	47749	-35.438	7.32	-0.416	-0.950	-14.100	-14.504
AUG 21	47759	-35.287	8.80	-0.376	-0.976	-14.188	-14.626
AUG 31	47769	-35.168	10.09	-0.323	-1.023	-14.439	-14.749
SEP 10	47779	-35.086	10.35	-0.274	-1.094	-14.604	-14.898
SEP 20	47789	-35.016	10.45	-0.235	-1.224	-14.790	-15.060
SEP 30	47799	-35.083	10.20	-0.203	-1.310	-14.948	-15.197
OCT 10	47809	-35.051	-	-0.141	-1.543	-15.474	-15.319
OCT 20	47819	-34.962	-	-0.100	-1.668	-16.140	-15.440
OCT 30	47829	-35.019	-	-0.071	-1.689	-16.806	-15.584
NOV 9	47839	-35.109	-	-0.036	-1.823	-17.406	-15.679
NOV 19	47849	-35.185	-	0.023	-1.975	-17.935	-15.757
NOV 29	47859	-35.202	-	0.051	-2.078	-18.466	-15.827
DEC 9	47869	-35.091	9.40	0.102	-2.099	-18.990	-15.831
DEC 19	47879	-35.207	9.35	0.160	-2.111	-19.433	-15.804
DEC 29	47889	-35.467	9.31	0.190	-2.113	-19.666	-15.790

TABLE 9 - (CONT.)

Unit is one microsecond

DATE 1989	MJD	UTC - UTC(k) NRLM (9)	OMH	ONRJ	ONBA	OP	ORB (10)
JAN 3	47529	-32.59	-8.82	-	-	-1.893	-12.689
JAN 13	47539	-33.05	-9.24	-	-	-1.854	-12.892
JAN 23	47549	-33.57	-9.44	-	-	-1.831	-13.035
FEB 2	47559	-33.890	-9.28	-	-	-1.825	-13.212
FEB 12	47569	-34.341	-9.38	-	-	-1.817	-13.573
FEB 22	47579	-34.758	-9.33	-	-	-1.807	-13.879
MAR 4	47589	-35.186	-9.29	-	-	-1.799	-14.147
MAR 14	47599	-35.634	-9.16	-	-	-1.806	-14.446
MAR 24	47609	-36.100	-9.12	-	-	-1.788	-14.694
APR 3	47619	-36.63	-9.13	-	-	-1.744	-14.965
APR 13	47629	-37.10	-9.20	-	-	-1.674	-15.314
APR 23	47639	-37.535	-9.09	-	-	-1.633	-15.626
MAY 3	47649	-37.994	-8.96	-	-	-1.602	-15.997
MAY 13	47659	-38.461	-9.23	-	-	-1.580	4.179
MAY 23	47669	-38.890	-9.25	-	-	-1.565	4.140
JUN 2	47679	-39.322	-9.36	-	-	-1.575	4.083
JUN 12	47689	-39.752	-9.41	-	-	-1.548	4.052
JUN 22	47699	-40.187	-9.24	-	-	-1.621	4.169
JUL 2	47709	-40.601	-9.46	16.422	-	-1.514	4.304
JUL 12	47719	-41.050	-9.41	15.714	-	-1.357	4.437
JUL 22	47729	-41.551	-9.32	15.115	-	-1.255	3.220
AUG 1	47739	-42.038	-9.13	14.760	-	-1.154	1.167
AUG 11	47749	-42.510	-9.26	13.944	-	-1.065	1.346
AUG 21	47759	-42.964	-9.31	13.236	-	-0.984	1.587
AUG 31	47769	-43.422	-9.15	12.628	-	-0.849	1.873
SEP 10	47779	-43.869	-9.56	11.839	-	-0.733	2.150
SEP 20	47789	-44.347	-9.52	11.636	-	-0.636	2.393
SEP 30	47799	-44.794	-9.55	11.725	-	-0.512	2.592
OCT 10	47809	-45.198	-9.76	11.752	-	-0.334	2.846
OCT 20	47819	-45.624	-9.74	11.802	-	-0.197	3.073
OCT 30	47829	-45.032	-9.89	11.634	-	-0.063	3.206
NOV 9	47839	-43.581	-9.13	11.510	-	-0.007	3.382
NOV 19	47849	-42.103	-9.38	11.334	-	0.006	3.527
NOV 29	47859	-40.706	-9.18	11.260	-	-0.026	3.707
DEC 9	47869	-39.277	-9.67	11.168	-	-0.056	4.052
DEC 19	47879	-37.888	-9.10	11.284	-	-0.088	4.132
DEC 29	47889	-36.565	-9.18	11.317	-	-0.139	4.821

TABLE 9 - (CONT.)

Unit is one microsecond

DATE 1989	MJD	UTC - UTC(k) PEL	PKNM	PTB	RC (11)	ROA	SO
JAN 3	47529	-	4.59	4.103	14.72	7.474	2.42
JAN 13	47539	-	5.18	4.082	14.36	7.510	2.61
JAN 23	47549	-	5.55	4.081	13.93	7.485	2.58
FEB 2	47559	-	5.97	4.140	13.54	7.463	2.68
FEB 12	47569	-	6.13	4.157	13.13	7.455	2.58
FEB 22	47579	-	6.01	4.195	12.92	7.396	2.58
MAR 4	47589	-	5.98	4.232	12.33	7.398	2.63
MAR 14	47599	-	5.89	4.279	12.16	7.392	2.54
MAR 24	47609	-	5.86	4.283	11.91	7.375	2.58
APR 3	47619	-	5.78	4.294	11.67	7.248	2.56
APR 13	47629	-	5.72	4.294	11.36	7.329	2.62
APR 23	47639	-	5.81	4.279	11.20	7.328	2.70
MAY 3	47649	-	6.01	4.280	10.89	7.362	2.66
MAY 13	47659	-	6.11	4.228	10.52	7.378	2.51
MAY 23	47669	-	6.08	4.224	10.29	7.397	2.44
JUN 2	47679	-	5.93	4.218	-0.04	7.463	2.41
JUN 12	47689	2.478	5.74	4.191	-0.36	7.557	2.47
JUN 22	47699	2.441	5.42	4.164	-0.66	7.640	2.55
JUL 2	47709	-	5.14	4.159	-1.03	7.708	2.55
JUL 12	47719	2.276	4.77	4.139	-1.47	7.845	2.61
JUL 22	47729	2.235	4.43	4.093	-1.75	8.001	2.62
AUG 1	47739	2.010	3.97	4.087	-2.00	8.285	2.67
AUG 11	47749	1.847	3.58	4.018	-2.15	8.508	2.57
AUG 21	47759	1.810	3.03	4.006	-2.20	8.569	2.65
AUG 31	47769	1.626	2.82	4.022	-2.22	8.698	2.68
SEP 10	47779	1.547	2.64	4.016	-2.19	8.789	2.69
SEP 20	47789	1.593	2.15	3.976	-2.20	8.882	2.78
SEP 30	47799	1.627	1.55	3.939	-2.21	8.963	2.87
OCT 10	47809	-	1.01	3.906	-2.33	9.051	3.08
OCT 20	47819	-	0.27	3.871	-2.31	9.178	3.06
OCT 30	47829	-	-0.06	3.848	-2.23	9.254	3.20
NOV 9	47839	-	-0.22	3.819	-2.49	9.331	3.34
NOV 19	47849	-	-0.34	3.820	-2.67	9.441	3.49
NOV 29	47859	-	-0.35	3.829	-2.57	9.522	3.53
DEC 9	47869	-	-0.66	3.839	-2.72	9.657	3.61
DEC 19	47879	-	-1.32	3.815	-2.72	9.778	3.74
DEC 29	47889	-	-1.66	3.784	-2.49	9.862	3.76

TABLE 9 - (CONT.)

Unit is one microsecond

DATE 1989	MJD	UTC - UTC(k) STA	SU (12)	TAO	TL (13)	TP (14)
JAN 3	47529	-0.172	16.66	-2.592	-6.018	-0.86
JAN 13	47539	0.097	16.66	-2.615	1.128	-0.95
JAN 23	47549	0.451	16.48	-2.642	1.313	-0.79
FEB 2	47559	0.907	16.12	-2.655	1.524	-0.26
FEB 12	47569	1.372	15.99	-2.710	1.644	-0.20
FEB 22	47579	1.852	15.86	-2.704	1.803	-0.16
MAR 4	47589	2.209	15.71	-2.712	1.970	-0.25
MAR 14	47599	2.209	15.82	-2.752	2.103	-0.18
MAR 24	47609	2.248	15.78	-2.803	2.259	-0.19
APR 3	47619	2.307	15.59	-2.872	2.30	-0.29
APR 13	47629	2.267	15.46	-2.900	2.42	-0.40
APR 23	47639	2.193	15.25	-2.976	2.48	-0.41
MAY 3	47649	2.067	15.17	-3.023	2.201	-0.39
MAY 13	47659	1.962	14.93	-3.076	2.316	-0.60
MAY 23	47669	1.799	14.77	-3.148	2.406	-0.87
JUN 2	47679	1.669	14.52	-3.234	2.562	-1.19
JUN 12	47689	1.600	14.50	-3.295	2.666	-1.35
JUN 22	47699	1.546	14.28	-3.377	2.614	-1.15
JUL 2	47709	1.394	14.06	-3.427	2.866	-1.28
JUL 12	47719	1.207	13.93	-3.490	2.857	-1.23
JUL 22	47729	1.026	13.92	-3.584	2.823	-1.14
AUG 1	47739	0.819	13.50	-3.671	2.693	-0.97
AUG 11	47749	0.562	13.28	-3.790	2.594	-0.87
AUG 21	47759	0.322	13.05	-3.880	2.476	-1.01
AUG 31	47769	0.210	12.93	-3.963	2.369	-0.81
SEP 10	47779	0.045	12.80	-4.033	2.276	-0.83
SEP 20	47789	-0.071	12.68	-4.144	2.204	-0.60
SEP 30	47799	-0.057	12.55	-4.214	2.137	-0.57
OCT 10	47809	0.069	12.43	-4.250	2.083	-0.50
OCT 20	47819	0.141	12.31	-4.335	2.019	-0.23
OCT 30	47829	0.218	12.19	-4.406	1.876	0.20
NOV 9	47839	0.292	12.06	-4.487	1.704	1.44
NOV 19	47849	0.343	11.94	-4.542	1.601	1.49
NOV 29	47859	0.392	11.75	-4.614	1.410	1.86
DEC 9	47869	0.384	11.75	-4.672	1.345	1.82
DEC 19	47879	0.347	11.62	-4.730	1.258	1.68
DEC 29	47889	0.331	11.29	-4.807	1.224	1.48

TABLE 9 - (CONT.)

Unit is one microsecond

DATE 1989		MJD	UTC - UTC(k) TUG	USNO	VSL (15)	YUZM	ZIPE
JAN	3	47529	-4.221	-1.343	0.827	6.72	-0.05
JAN	13	47539	-3.995	-1.298	0.864	6.40	-0.13
JAN	23	47549	-3.752	-1.242	0.881	6.14	-0.16
FEB	2	47559	-3.491	-1.189	0.967	5.76	-0.17
FEB	12	47569	-3.236	-1.151	1.030	5.56	-0.22
FEB	22	47579	-2.957	-1.109	1.039	5.51	-0.18
MAR	4	47589	-2.714	-1.068	0.965	5.62	0.04
MAR	14	47599	-2.489	-1.035	1.002	5.71	0.13
MAR	24	47609	-2.262	-1.013	0.998	5.89	0.16
APR	3	47619	-2.009	-0.989	1.016	6.04	0.25
APR	13	47629	-1.785	-0.960	0.986	6.24	0.34
APR	23	47639	-1.534	-0.953	0.994	6.60	0.35
MAY	3	47649	-1.320	-0.941	0.970	6.99	0.28
MAY	13	47659	-1.079	-0.931	1.018	7.52	0.10
MAY	23	47669	-0.828	-0.933	1.064	8.33	-0.09
JUN	2	47679	-0.544	-0.940	1.125	8.92	-0.19
JUN	12	47689	-0.270	-0.938	1.111	9.95	-0.24
JUN	22	47699	-0.030	-0.951	1.168	10.73	-0.30
JUL	2	47709	0.209	-0.958	1.143	11.89	-0.36
JUL	12	47719	0.501	-0.964	1.245	13.31	-0.44
JUL	22	47729	0.756	-0.976	1.327	14.19	-0.45
AUG	1	47739	1.002	-0.994	1.442	14.98	-0.33
AUG	11	47749	1.254	-1.000	1.502	16.17	-0.22
AUG	21	47759	1.504	-0.991	1.576	17.69	-0.10
AUG	31	47769	1.774	-0.972	1.692	18.75	-0.02
SEP	10	47779	2.013	-0.975	1.764	19.25	0.04
SEP	20	47789	2.235	-0.972	1.826	19.97	0.13
SEP	30	47799	2.476	-0.943	1.907	20.43	0.03
OCT	10	47809	2.680	-0.879	1.961	20.52	-0.06
OCT	20	47819	2.873	-0.822	1.988	20.47	-0.18
OCT	30	47829	3.057	-0.785	2.017	21.08	-0.28
NOV	9	47839	3.268	-0.771	2.013	21.52	-0.32
NOV	19	47849	3.483	-0.754	2.072	21.30	-0.27
NOV	29	47859	3.733	-0.767	2.067	20.78	-0.12
DEC	9	47869	3.983	-0.872	2.170	19.82	-0.01
DEC	19	47879	4.223	-0.936	2.168	19.28	0.18
DEC	29	47889	4.459	-1.010	2.201	19.18	0.19

TABLE 9 - (CONT.)

NOTES

(1) AOS . Time step of UTC(AOS) of +30 μs on MJD = 47787 .

(2) APL . Change of master clock on MJD = 47795 .

(3) AUS . The time scale previously designated as UTC(AUS) became TA(AUS) on 1st of January 1989, without time or frequency step. A new time scale UTC(AUS) designated by TS(AUS) by AUS has been created.

(4) BEV . Time step of UTC(BEV) of -20 μs on MJD = 47654.26

(5) IEN . Change of master clock on MJD = 47549 .

(6) IFAG. Time step of UTC(IFAG) of +2 μs on MJD = 47549 .
Interpolated value for MJD = 47659 .

(7) KSRI. Change of master clock on MJD = 47665.08

(8) NAOM. Time step of UTC-UTC(NAOM) of about -0.5 μs due to introduction of GPS link on MJD = 47589 .

(9) NRLM. Introduction of GPS link on MJD = 47559 .
LORAN-C instead of GPS for MJD=47619 and MJD=47629 .
Change of master clock on MJD = 47822 .

(10) ORB . Time step of UTC(ORB) of -20.4 μs on MJD = 47654.5

(11) RC . Time step of UTC(RC) of +10 μs on MJD = 47678 .

(12) SU . From MJD = 47769 to MJD = 47859, interpolated values using clock transportations reported in Table 6.

(13) TL . Time step of UTC(TL) of -7 μs on MJD = 47535.125
LORAN-C instead of GPS from MJD=47619 to MJD=47639 .
The time step of UTC-UTC(TL) of about +0.38 μs between MJD=47639 and MJD=47649 is due to the reintroduction of the GPS time link for TL.

(14) TP . The apparent time step on MJD = 47839 results from a recalibration of the TV link between TP and PTB.

(15) VSL . Time step of UTC(VSL) of +3 μs on MJD = 47524.42

TABLE 9 B . TAI - GPS TIME and UTC - GPS TIME

TAI - GPS TIME = 19 s + Co
UTC - GPS TIME = -5 s + Co

(see explanations, Part A)

Date 1988/89	MJD	Co (ns) 0hUTC	DC(ns) PRN11 NAV 8 13h42m	PRN 6 NAV 3 18h54m	PRN 9 NAV 6 19h54m	PRN13 NAV 9 22h18m	PRN12 NAV10 22h34m	PRN 3 NAV11 23h14m
DEC 31	47526	-1377	9	4	8	-14	2	38
JAN 1	47527	-1376	0	0	8	3	15	61
JAN 2	47528	-1382	5	-9	-6	8	-10	48
JAN 3	47529	-1380	9	1	-3	-7	-35	69
JAN 4	47530	-1359	19	13	16	-7	-10	-
JAN 5	47531	-1344	-14	-5	6	-16	-17	-
JAN 6	47532	-1346	2	3	12	-5	-19	-
JAN 7	47533	-1350	2	4	13	-6	-21	-16
JAN 8	47534	-1346	8	6	13	-11	-2	-5
JAN 9	47535	-1341	10	-2	6	-6	-18	-
JAN 10	47536	-1341	5	9	3	0	-5	-7
JAN 11	47537	-1343	5	-21	-6	-1	-6	-2
JAN 12	47538	-1345	7	4	8	-9	4	-2
JAN 13	47539	-1345	6	5	6	-17	-14	1
JAN 14	47540	-1346	-3	-1	9	-39	-35	-1
JAN 15	47541	-1341	3	9	7	-16	4	-4
JAN 16	47542	-1338	-1	7	5	5	-17	-1
JAN 17	47543	-1340	19	-1	3	-21	-17	-1
JAN 18	47544	-1344	20	23	8	-2	-8	2
JAN 19	47545	-1341	-3	-2	-4	-4	-7	-9
JAN 20	47546	-1334	7	-5	7	4	2	13
JAN 21	47547	-1328	4	0	-5	-14	2	0
JAN 22	47548	-1327	7	-6	6	-2	-11	0
JAN 23	47549	-1325	11	13	3	-13	-15	-3
JAN 24	47550	-1317	4	4	-4	1	-16	2
JAN 25	47551	-1308	10	2	4	10	-11	1
JAN 26	47552	-1305	1	-2	-10	5	-17	3
JAN 27	47553	-1307	13	6	-5	-12	-4	8
JAN 28	47554	-1304	13	3	-6	2	-3	2
JAN 29	47555	-1300	12	0	-10	4	-7	2
JAN 30	47556	-1298	7	-7	7	-12	-2	0
JAN 31	47557	-1296	6	4	11	-4	-10	1
FEB 1	47558	-1296	7	-7	0	-4	-18	-1

TABLE 9 B . TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1989	MJD	Co (ns) 0hUTC	DC(ns) PRN11 NAV 8 11h38m	PRN 6 NAV 3 16h50m	PRN 9 NAV 6 17h50m	PRN13 NAV 9 20h14m	PRN12 NAV10 20h30m	PRN 3 NAV11 21h10m
JAN 31	47557	-1296	6	4	11	-4	-10	1
FEB 1	47558	-1296	7	-7	0	-4	-18	-1
FEB 2	47559	-1293	15	1	0	-2	5	2
FEB 3	47560	-1295	12	-2	-7	-16	-9	-2
FEB 4	47561	-1295	19	5	0	4	-19	2
FEB 5	47562	-1294	8	-5	-2	-14	3	-6
FEB 6	47563	-1291	12	-3	-1	2	-3	3
FEB 7	47564	-1289	7	1	-3	5	0	5
FEB 8	47565	-1292	4	4	17	-13	3	3
FEB 9	47566	-1297	2	33	25	-8	-10	-4
FEB 10	47567	-1294	10	13	-1	5	-3	2
FEB 11	47568	-1288	8	12	-8	-8	0	-2
FEB 12	47569	-1292	-3	-4	-6	-19	-5	0
FEB 13	47570	-1297	20	2	0	6	-1	2
FEB 14	47571	-1297	3	-2	-2	-12	-2	0
FEB 15	47572	-1296	5	-2	-1	4	3	-2
FEB 16	47573	-1294	7	17	0	1	-5	5
FEB 17	47574	-1298	7	-4	-9	-4	7	2
FEB 18	47575	-1303	12	-1	-2	-3	-13	5
FEB 19	47576	-1301	21	2	-7	3	1	-4
FEB 20	47577	-1296	15	2	-4	-4	5	-1
FEB 21	47578	-1289	2	4	-7	-4	-28	-3
FEB 22	47579	-1278	13	-3	9	-14	-3	-4
FEB 23	47580	-1265	19	-7	8	-27	4	-16
FEB 24	47581	-1262	-1	2	-11	-3	-5	2
FEB 25	47582	-1267	18	14	-7	-3	-11	4
FEB 26	47583	-1268	8	-3	-13	7	1	3
FEB 27	47584	-1263	16	0	-6	7	-3	8
FEB 28	47585	-1259	25	0	-3	-5	-14	4
MAR 1	47586	-1259	3	-2	-3	6	0	7

TABLE 9 B . TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1989	MJD	Co (ns) 0hUTC	DC(ns) PRN11 NAV 8 9h46m	PRN 6 NAV 3 14h58m	PRN 9 NAV 6 15h58m	PRN13 NAV 9 18h22m	PRN12 NAV10 18h38m	PRN 3 NAV11 19h18m
FEB 28	47585	-1259	25	0	-3	-5	-14	4
MAR 1	47586	-1259	3	-2	-3	6	0	7
MAR 2	47587	-1260	-1	4	2	-13	-6	-2
MAR 3	47588	-1261	-2	8	6	-8	-4	3
MAR 4	47589	-1267	1	4	10	-9	-9	1
MAR 5	47590	-1281	4	2	-3	-6	4	1
MAR 6	47591	-1293	6	-1	-3	-2	-8	-7
MAR 7	47592	-1301	10	3	9	-	-	-
MAR 8	47593	-1306	5	-5	-10	5	-7	-3
MAR 9	47594	-1312	2	0	-3	18	11	0
MAR 10	47595	-1316	12	-3	-3	0	-	-
MAR 11	47596	-1316	-5	1	-6	-4	4	-1
MAR 12	47597	-1309	9	3	-7	-4	2	0
MAR 13	47598	-1297	5	2	0	9	1	-6
MAR 14	47599	-1288	-4	6	-3	-5	-5	-1
MAR 15	47600	-1280	2	2	-4	-8	8	4
MAR 16	47601	-1269	3	1	-4	-5	2	0
MAR 17	47602	-1258	-3	2	2	15	6	10
MAR 18	47603	-1249	-4	-3	-7	5	-4	3
MAR 19	47604	-1242	-3	1	-4	-2	3	7
MAR 20	47605	-1236	2	10	-7	0	-4	-2
MAR 21	47606	-1228	-1	10	-8	-2	4	-11
MAR 22	47607	-1219	-4	15	-2	-1	6	-1
MAR 23	47608	-1211	7	9	-9	-4	-3	-7
MAR 24	47609	-1207	5	8	-12	-2	2	1
MAR 25	47610	-1201	0	16	7	-9	-3	-7
MAR 26	47611	-1192	-7	6	6	-21	-12	-3
MAR 27	47612	-1185	0	8	0	-12	9	1
MAR 28	47613	-1175	-3	8	-5	-12	-1	-9
MAR 29	47614	-1167	10	2	6	-2	13	3
MAR 30	47615	-1163	-9	7	8	-16	-3	-7
MAR 31	47616	-1161	15	6	4	-15	20	-7
APR 1	47617	-1158	-9	18	5	-8	12	-6

TABLE 9 B . TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1989	MJD	Co (ns) 0hUTC	DC(ns) PRN11 NAV 8 7h42m	PRN 6 NAV 3 12h54m	PRN 9 NAV 6 13h54m	PRN13 NAV 9 16h18m	PRN12 NAV10 16h34m	PRN 3 NAV11 17h14m
MAR 31	47616	-1161	15	6	4	-15	20	-7
APR 1	47617	-1158	-9	18	5	-8	12	-6
APR 2	47618	-1155	3	-2	1	-15	9	-14
APR 3	47619	-1154	-10	17	10	0	-8	-7
APR 4	47620	-1150	-8	1	4	-10	-3	-6
APR 5	47621	-1142	-7	9	5	0	-6	-4
APR 6	47622	-1134	-14	6	19	-18	15	-3
APR 7	47623	-1132	-13	0	5	0	-1	-5
APR 8	47624	-1132	-16	7	-11	-9	0	-3
APR 9	47625	-1131	5	11	10	-18	0	-4
APR 10	47626	-1137	-2	4	5	-10	3	-7
APR 11	47627	-1144	-1	3	3	-28	-1	-10
APR 12	47628	-1141	-3	7	10	-17	-15	-3
APR 13	47629	-1130	6	6	-3	-10	0	1
APR 14	47630	-1123	-4	4	7	-9	11	-5
APR 15	47631	-1125	-9	1	-6	-2	4	1
APR 16	47632	-1129	-2	1	-1	-3	8	-7
APR 17	47633	-1129	-6	7	-1	9	-4	-3
APR 18	47634	-1125	3	14	10	-14	13	1
APR 19	47635	-1123	-8	-6	5	-21	-4	-12
APR 20	47636	-1117	-6	10	7	0	-19	-4
APR 21	47637	-1109	-23	5	25	32	16	44
APR 22	47638	-1114	-17	0	5	-12	9	0
APR 23	47639	-1123	-14	0	7	-11	-22	-11
APR 24	47640	-1124	4	7	11	-1	-7	-6
APR 25	47641	-1119	-10	13	4	-17	22	-7
APR 26	47642	-1114	-10	3	7	-9	6	-9
APR 27	47643	-1111	-11	2	17	-12	5	-13
APR 28	47644	-1112	-11	12	4	-17	7	-8
APR 29	47645	-1118	-18	10	5	-10	7	-
APR 30	47646	-1126	-	-	-	-	-	-
MAY 1	47647	-1131	-	5	-2	-4	7	-3

TABLE 9 B . TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1989	MJD	Co (ns) 0hUTC	DC(ns) PRN11 NAV 8 5h42m	PRN 6 NAV 3 10h54m	PRN 9 NAV 6 11h54m	PRN13 NAV 9 14h18m	PRN12 NAV10 14h34m	PRN 3 NAV11 15h14m
APR 30	47646	-1126	-	-	-	-	-	-
MAY 1	47647	-1131	-	5	-2	-4	7	-3
MAY 2	47648	-1131	-6	3	-6	0	-3	-4
MAY 3	47649	-1130	-4	12	2	7	-2	4
MAY 4	47650	-1137	-11	7	-3	-10	-3	1
MAY 5	47651	-1145	-6	4	1	1	-2	2
MAY 6	47652	-1144	-9	9	-1	-6	6	-2
MAY 7	47653	-1137	-3	8	-3	-3	-2	-4
MAY 8	47654	-1134	0	7	-4	-22	19	12
MAY 9	47655	-1134	-2	-3	-2	-5	0	0
MAY 10	47656	-1131	-5	3	-2	6	-10	5
MAY 11	47657	-1122	2	-2	1	-18	-10	18
MAY 12	47658	-1115	-10	-9	4	-12	16	8
MAY 13	47659	-1111	0	7	3	-19	-6	4
MAY 14	47660	-1109	-18	3	1	-1	-7	4
MAY 15	47661	-1100	16	-4	4	-1	5	3
MAY 16	47662	-1088	-2	0	0	6	2	-1
MAY 17	47663	-1078	-8	2	2	2	-11	5
MAY 18	47664	-1074	-7	6	0	7	-7	13
MAY 19	47665	-1073	-14	4	-4	7	-13	15
MAY 20	47666	-1074	-	0	-6	7	-9	12
MAY 21	47667	-1069	-8	2	-10	3	0	14
MAY 22	47668	-1067	-8	4	-2	6	-11	9
MAY 23	47669	-1068	-3	6	-1	5	-7	5
MAY 24	47670	-1072	-6	-2	-7	-3	-11	17
MAY 25	47671	-1071	-7	4	4	-3	-3	14
MAY 26	47672	-1071	-5	3	4	3	-5	1
MAY 27	47673	-1072	-16	-2	6	5	-10	6
MAY 28	47674	-1069	-4	-4	5	-6	-7	17
MAY 29	47675	-1064	-9	3	-1	-1	-11	15
MAY 30	47676	-1060	-	-	-	3	-16	10
MAY 31	47677	-1058	-4	3	0	-2	-3	10
JUN 1	47678	-1056	-13	3	-4	2	-6	19

TABLE 9 B . TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1989	MJD	Co (ns) 0hUTC	DC(ns) PRN11 NAV 8 3h38m	PRN 6 NAV 3 8h50m	PRN 9 NAV 6 9h50m	PRN13 NAV 9 12h14m	PRN12 NAV10 12h30m	PRN 3 NAV11 13h10m
MAY 31	47677	-1058	-4	3	0	-2	-3	10
JUN 1	47678	-1056	-13	3	-4	2	-6	19
JUN 2	47679	-1054	-17	-2	0	9	-15	22
JUN 3	47680	-1054	-17	0	0	0	0	15
JUN 4	47681	-1057	-6	2	-11	9	-13	9
JUN 5	47682	-1056	-16	7	2	12	-6	16
JUN 6	47683	-1054	-11	3	2	-8	-16	9
JUN 7	47684	-1053	-18	9	-1	5	-3	7
JUN 8	47685	-1048	-21	-2	-2	5	-3	15
JUN 9	47686	-1047	-5	-	-	-	-	-
JUN 10	47687	-1052	-	-	-	-	-	-
JUN 11	47688	-1065	-	-10	2	-7	3	33
JUN 12	47689	-1076	-18	0	-4	7	-6	18
JUN 13	47690	-1082	-5	-19	-14	4	-11	18
JUN 14	47691	-1080	-32	-2	-12	11	1	18
JUN 15	47692	-1077	-33	2	-5	15	-16	13
JUN 16	47693	-1081	-29	-7	-7	12	-8	12
JUN 17	47694	-1085	-2	-13	-17	5	-2	16
JUN 18	47695	-1081	-28	-5	-8	6	2	13
JUN 19	47696	-1077	-1	-	-	-	1	-
JUN 20	47697	-1080	-2	-2	-3	-1	-16	9
JUN 21	47698	-1088	-11	-2	-7	-12	0	15
JUN 22	47699	-1088	-10	-2	-4	-6	2	11
JUN 23	47700	-1073	-3	0	-3	5	-4	16
JUN 24	47701	-1072	-9	-7	-7	17	-8	12
JUN 25	47702	-1080	-3	-13	-13	1	-1	17
JUN 26	47703	-1088	-7	1	-4	1	-10	15

Date 1989	MJD	Co (ns) 0hUTC	DC(ns) PRN11 NAV 8 0h24m	PRN14 NAV14 2h48m	PRN 6 NAV 3 6h32m	PRN 9 NAV 6 7h52m	PRN12 NAV10 10h48m	PRN13 NAV 9 11h52m	PRN 3 NAV11 13h12m
JUN 27	47704	-1093	-	12	-2	-7	-10	-4	10
JUN 28	47705	-1084	-3	1	4	-5	7	-5	7
JUN 29	47706	-1085	4	23	9	-5	-6	-8	-2
JUN 30	47707	-1096	-3	10	10	6	12	-2	-10
JUL 1	47708	-1115	-4	3	1	-3	2	-14	6

TABLE 9 B . TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1989	MJD	Co (ns) 0hUTC	DC(ns) PRN11 NAV 8 0h12m	PRN14 NAV14 2h36m	PRN 6 NAV 3 6h20m	PRN 9 NAV 6 7h40m	PRN12 NAV10 10h36m	PRN13 NAV 9 11h40m	PRN 3 NAV11 13h00m
JUN 30	47707	-1096	-3	10	10	6	12	-2	-10
JUL 1	47708	-1115	-4	3	1	-3	2	-14	6
JUL 2	47709	-1131	-	-	-1	-3	7	6	4
JUL 3	47710	-1140	-11	-	16	32	-17	-21	7
JUL 4	47711	-1153	-1	-	-3	4	-6	1	4
JUL 5	47712	-1167	1	-	-9	8	2	5	2
JUL 6	47713	-1182	-2	-	5	0	-1	-2	6
JUL 7	47714	-1196	-7	-	-10	-1	1	-5	7
JUL 8	47715	-1205	-1	-	1	5	1	-2	8
JUL 9	47716	-1211	-7	-	7	-4	-4	-7	8
JUL 10	47717	-1221	-5	-	-8	7	3	3	5
JUL 11	47718	-1234	-1	-	2	-10	2	10	5
JUL 12	47719	-1244	-6	-	-5	2	-10	-9	6
JUL 13	47720	-1256	-7	-	-2	-1	6	2	3
JUL 14	47721	-1270	-1	-	7	2	7	3	5
JUL 15	47722	-1291	1	-	-3	-3	-21	-15	-3
JUL 16	47723	-1315	-14	-4	0	6	8	-8	6
JUL 17	47724	-1335	-15	27	8	14	-11	-10	5
JUL 18	47725	-1352	8	-9	2	5	5	2	-2
JUL 19	47726	-1367	0	10	0	0	3	-5	2
JUL 20	47727	-1383	1	11	-9	-8	-21	-7	1
JUL 21	47728	-1399	31	45	7	6	10	-5	17
JUL 22	47729	-1413	17	-8	-11	-7	0	1	3
JUL 23	47730	-1424	12	-	15	22	35	29	29
JUL 24	47731	-1433	-4	-	-7	5	-2	-7	-6
JUL 25	47732	-1438	8	-	-2	-4	0	-9	7
JUL 26	47733	-1432	7	-	-3	5	-18	-4	2
JUL 27	47734	-1424	3	-	-2	3	3	2	2
JUL 28	47735	-1419	0	-	-6	4	-6	-2	-3
JUL 29	47736	-1419	5	-	-1	-5	-24	-6	-9
JUL 30	47737	-1417	0	0	7	10	33	2	6
JUL 31	47738	-1415	2	-9	-	-5	-10	-11	-4
AUG 1	47739	-1411	-6	5	9	5	6	-7	0

TABLE 9 B . TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1989	MJD	Co (ns) 0hUTC	PRN11 NAV 8 22h 4m	PRN14 NAV14 0h32m	PRN 6 NAV 3 4h16m	PRN 9 NAV 6 5h36m	PRN12 NAV10 8h32m	PRN13 NAV 9 9h36m	PRN 3 NAV11 10h56m
			DC(ns)						
JUL 31	47738	-1415	2	-9	-	-5	-10	-11	-4
AUG 1	47739	-1411	-6	5	9	5	6	-7	0
AUG 2	47740	-1405	-2	-	-	-	-1	-6	3
AUG 3	47741	-1402	6	0	3	6	10	-5	-3
AUG 4	47742	-1403	13	-12	-6	0	5	-4	0
AUG 5	47743	-1402	-8	-1	-4	3	-14	-19	-3
AUG 6	47744	-1400	10	-	10	2	10	1	-2
AUG 7	47745	-1397	2	-	1	-2	1	-19	-4
AUG 8	47746	-1395	-4	-	0	3	2	-5	1
AUG 9	47747	-1388	13	-	5	0	-16	-5	-3
AUG 10	47748	-1378	3	-	-6	4	5	-11	1
AUG 11	47749	-1367	2	-	-2	1	-3	-13	-4
AUG 12	47750	-1357	4	-	-2	3	10	0	0
AUG 13	47751	-1349	4	3	0	3	-27	-7	-4
AUG 14	47752	-1344	9	-13	1	12	-14	-13	1
AUG 15	47753	-1339	-6	-2	3	7	-9	-2	-7
AUG 16	47754	-1334	6	3	2	8	16	8	6
AUG 17	47755	-1332	4	-1	1	-18	-4	-12	-10
AUG 18	47756	-1333	-7	5	17	-	-5	11	2
AUG 19	47757	-1334	10	13	-9	-	21	-22	1
AUG 20	47758	-1333	-17	-	-5	12	-4	0	2
AUG 21	47759	-1331	-12	-	-26	-14	14	8	6
AUG 22	47760	-1325	-2	-	14	-9	7	0	1
AUG 23	47761	-1317	-3	-	25	-6	-13	-10	1
AUG 24	47762	-1306	-1	-	19	1	-20	4	-1
AUG 25	47763	-1295	2	-	12	0	-4	-16	-6
AUG 26	47764	-1289	-3	-	7	4	-5	-4	-7
AUG 27	47765	-1283	14	-1	-14	14	-22	8	-15
AUG 28	47766	-1281	8	-12	14	12	2	3	2
AUG 29	47767	-1285	0	4	1	-17	-10	-14	-1
AUG 30	47768	-1284	23	6	1	-11	-13	7	3
AUG 31	47769	-1274	9	-14	7	11	-14	10	0
SEP 1	47770	-1268	-8	-1	-4	11	-17	-4	0

TABLE 9 B . TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1989	MJD	Co (ns) 0hUTC	PRN11 NAV 8 20h 0m	PRN14 NAV14 22h24m	PRN 6 NAV 3 2h12m	PRN 9 NAV 6 3h32m	PRN12 NAV10 6h28m	PRN13 NAV 9 7h32m	PRN 3 NAV11 8h52m
			DC(ns)						
AUG 31	47769	-1274	9	-14	7	11	-14	10	0
SEP 1	47770	-1268	-8	-1	-4	11	-17	-4	0
SEP 2	47771	-1269	7	-5	9	-1	20	21	7
SEP 3	47772	-1267	-	-6	-	-	-	-	-
SEP 4	47773	-1264	12	1	-1	-9	6	-2	3
SEP 5	47774	-1260	3	9	-2	-7	0	-9	2
SEP 6	47775	-1257	16	-13	3	3	-2	-12	4
SEP 7	47776	-1253	13	-2	-2	-4	-6	-15	-10
SEP 8	47777	-1246	12	-2	9	-2	-2	0	-2
SEP 9	47778	-1244	16	23	-8	-21	3	-1	-1
SEP 10	47779	-1244	12	-	4	-2	-19	-17	-12
SEP 11	47780	-1244	4	-	6	5	5	-6	-5
SEP 12	47781	-1244	28	-	12	9	-9	-6	32
SEP 13	47782	-1247	11	-	8	-7	-4	-12	-10
SEP 14	47783	-1244	11	-	1	4	-3	-15	-6
SEP 15	47784	-1238	7	-	6	-2	6	4	3
SEP 16	47785	-1231	0	-	-6	0	-3	-7	-3
SEP 17	47786	-1224	4	-	-3	-5	3	3	4
SEP 18	47787	-1217	-7	-	19	-1	2	-8	-2
SEP 19	47788	-1217	21	-	-1	1	-4	-5	3
SEP 20	47789	-1218	6	-	-3	3	7	-8	-13
SEP 21	47790	-1216	12	-	1	6	-13	-1	-6
SEP 22	47791	-1211	8	-	2	7	3	-5	-6
SEP 23	47792	-1209	9	-17	-4	5	0	-5	-3
SEP 24	47793	-1207	6	-	-3	8	-13	-1	-11
SEP 25	47794	-1207	8	-	-1	7	10	-3	-5
SEP 26	47795	-1210	4	-	-2	5	6	-7	-8
SEP 27	47796	-1215	2	-	0	3	-13	1	-9
SEP 28	47797	-1223	3	-	2	7	4	-2	0
SEP 29	47798	-1231	-	-	-	-	-	-	-
SEP 30	47799	-1238	-	-	-	-	-	-	-
OCT 1	47800	-1235	-	-	-	-	-	-	-

TABLE 9 B . TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1989	MJD	Co (ns) 0hUTC	DC(ns) PRN11 NAV 8 18h 0m	PRN14 NAV14 20h24m	PRN 6 NAV 3 0h12m	PRN 9 NAV 6 1h32m	PRN12 NAV10 4h28m	PRN13 NAV 9 5h32m	PRN 3 NAV11 6h52m
SEP 30	47799	-1238	-	-	-	-	-	-	-
OCT 1	47800	-1235	-	-	-	-	-	-	-
OCT 2	47801	-1223	-	-	-	-	-	-	-
OCT 3	47802	-1204	11	-6	7	-7	1	-6	-8
OCT 4	47803	-1183	12	-3	-	13	23	1	11
OCT 5	47804	-1171	20	-9	-6	-11	-4	-7	-16
OCT 6	47805	-1150	23	-6	6	-2	-	-15	-9
OCT 7	47806	-1119	12	10	-5	0	-3	15	1
OCT 8	47807	-1091	9	-	-21	-6	7	-21	-16
OCT 9	47808	-1064	9	-	-3	-7	23	7	9
OCT 10	47809	-1035	18	-	2	4	-13	-10	-9
OCT 11	47810	-1011	15	-	-8	7	26	2	-4
OCT 12	47811	-990	17	-	8	-10	7	-8	-7
OCT 13	47812	-966	17	-	-12	-1	1	-3	-5
OCT 14	47813	-941	-	-	-9	-4	6	-	-
OCT 15	47814	-916	14	-	9	1	-10	2	-8
OCT 16	47815	-892	4	-1	-2	9	4	0	-
OCT 17	47816	-872	7	-	-1	-5	-10	-12	-5
OCT 18	47817	-845	9	-19	3	9	-4	-9	8
OCT 19	47818	-814	0	-7	-2	6	1	0	1
OCT 20	47819	-784	8	-12	5	-21	-4	-1	1
OCT 21	47820	-760	18	-9	-4	6	-5	-2	-1
OCT 22	47821	-743	3	-	-2	-	-1	-1	-6
OCT 23	47822	-729	18	-	1	0	-11	-8	-4
OCT 24	47823	-714	1	-	3	7	-6	10	1
OCT 25	47824	-704	-1	-	-11	-6	-3	-3	1
OCT 26	47825	-697	12	-	-1	12	3	-13	-7
OCT 27	47826	-688	9	-	-7	-4	7	-1	8
OCT 28	47827	-684	4	-	0	4	-10	-2	-3
OCT 29	47828	-683	19	-	-3	3	-4	0	-5
OCT 30	47829	-682	13	-	0	-4	-10	-1	-5
OCT 31	47830	-682	3	-	-2	6	-9	-7	-9
NOV 1	47831	-680	8	-	-8	3	9	3	3

TABLE 9 B . TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1989	MJD	Co (ns) 0hUTC	DC(ns) PRN11 NAV 8 15h56m	PRN14 NAV14 18h20m	PRN 6 NAV 3 22h 4m	PRN 9 NAV 6 23h24m	PRN12 NAV10 2h24m	PRN13 NAV 9 3h28m	PRN 3 NAV11 4h48m
OCT 31	47830	-682	3	-	-2	6	-9	-7	-9
NOV 1	47831	-680	8	-	-8	3	9	3	3
NOV 2	47832	-682	1	-	-4	-1	3	4	0
NOV 3	47833	-686	4	-	2	3	-5	-5	-6
NOV 4	47834	-680	8	-	-6	-3	-14	-5	-1
NOV 5	47835	-668	12	-1	-4	-6	-5	10	4
NOV 6	47836	-656	14	-9	1	0	18	-8	-1
NOV 7	47837	-644	6	-23	-7	-2	-1	-8	-5
NOV 8	47838	-633	13	-26	-4	-2	0	4	5
NOV 9	47839	-621	10	4	-4	-4	-11	-7	-3
NOV 10	47840	-614	6	1	-2	3	4	-10	1
NOV 11	47841	-610	1	-17	-2	-1	-10	8	4
NOV 12	47842	-612	3	-	-5	1	0	0	2
NOV 13	47843	-614	2	-	-1	3	-13	2	1
NOV 14	47844	-610	7	-	-5	-6	11	-10	7
NOV 15	47845	-599	14	-	-1	4	-7	-5	-1
NOV 16	47846	-591	-1	-	-	-	-15	2	3
NOV 17	47847	-588	-2	-	-4	2	-3	5	2
NOV 18	47848	-586	-3	-	-3	-6	5	5	4
NOV 19	47849	-582	0	8	-5	-3	5	-1	3
NOV 20	47850	-577	4	5	-2	4	-7	-8	0
NOV 21	47851	-569	7	-3	-7	-6	-5	2	12
NOV 22	47852	-564	10	16	-9	-7	-5	15	11
NOV 23	47853	-556	6	3	-13	-2	-9	-5	4
NOV 24	47854	-541	5	5	-12	-5	0	-6	14
NOV 25	47855	-521	9	26	-3	-4	-3	-6	-1
NOV 26	47856	-503	-2	-	-8	-2	8	2	7
NOV 27	47857	-491	1	-	-5	-3	-10	8	9
NOV 28	47858	-478	8	-	-3	4	-7	-12	4
NOV 29	47859	-461	2	-	-5	-4	-8	1	8
NOV 30	47860	-443	7	-	-10	-6	1	1	9
DEC 1	47861	-429	3	-	-10	-1	-1	-5	3

TABLE 9 B . TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1989	MJD	Co (ns) 0hUTC	DC(ns) PRN11 NAV 8 13h56m	PRN14 NAV14 16h20m	PRN 6 NAV 3 20h 4m	PRN 9 NAV 6 21h24m	PRN12 NAV10 0h24m	PRN13 NAV 9 1h28m	PRN 3 NAV11 2h48m
NOV 30	47860	-443	7	-	-10	-6	1	1	9
DEC 1	47861	-429	3	-	-10	-1	-1	-5	3
DEC 2	47862	-419	12	-	-	-27	8	-2	9
DEC 3	47863	-414	-4	-2	-14	-10	-42	-7	14
DEC 4	47864	-401	4	17	-1	1	-17	-6	4
DEC 5	47865	-381	4	7	-8	-2	-	11	7
DEC 6	47866	-367	5	2	-18	-10	-8	4	7
DEC 7	47867	-355	20	20	-6	-3	-5	0	-3
DEC 8	47868	-340	3	9	-10	-4	4	-2	4
DEC 9	47869	-325	12	9	-7	-5	-4	3	4
DEC 10	47870	-317	2	-	-8	-10	3	7	4
DEC 11	47871	-313	-2	-	-3	-3	15	-2	-1
DEC 12	47872	-311	3	-	-8	-1	7	5	2
DEC 13	47873	-309	2	-	-14	-6	7	-1	3

Date 1989/90	MJD	Co (ns) 0hUTC	DC(ns) PRN13 NAV 9 0h24m	PRN 3 NAV11 1h44m	PRN11 NAV 8 12h56m	PRN14 NAV14 15h20m	PRN 6 NAV 3 19h36m	PRN 9 NAV 6 22h32m	PRN12 NAV10 23h20m
DEC 14	47874	-323	-4	5	3	-	-6	-11	6
DEC 15	47875	-325	5	2	13	-	-7	-12	0
DEC 16	47876	-328	3	1	9	-	-9	-8	0
DEC 17	47877	-332	-5	5	-2	12	-12	-10	-6
DEC 18	47878	-333	4	10	11	8	-5	-11	2
DEC 19	47879	-336	-	4	1	12	-5	-3	-13
DEC 20	47880	-346	4	3	13	13	-2	-5	-12
DEC 21	47881	-362	1	7	8	-7	-8	-8	19
DEC 22	47882	-378	5	-6	12	-1	0	-7	-1
DEC 23	47883	-390	-3	-3	11	13	-11	-8	-1
DEC 24	47884	-405	-4	6	11	-2	-10	-4	-18
DEC 25	47885	-421	4	4	6	5	-5	-4	-1
DEC 26	47886	-438	2	3	1	4	2	-3	-7
DEC 27	47887	-453	2	-1	-4	20	-1	-6	-18
DEC 28	47888	-464	-7	4	10	-2	0	-9	5
DEC 29	47889	-472	0	-1	3	8	-2	-4	10
DEC 30	47890	-484	-12	6	-7	1	1	-9	0
DEC 31	47891	-496	3	5	0	-	8	-6	2
JAN 1	47892	-505	8	2	-1	-	4	-16	19

TABLE 10 - COMPARISONS BETWEEN ABSOLUTE TIME COMPARISONS AND THE BIPM RESULTS

The Table gives the differences between absolute time comparisons results and those derived from the data of Table 9 (before rounding-off)

A - CLOCK TRANSPORTATION

DATE 1989	MJD	TIME COMPARISONS	DIFFERENCE CLOCK TR. - BIPM (Unit : 1 microsecond)
MAR 5	47590.58	UTC(SU) - UTC(NPL)	-0.27
MAY 15	47661.70	UTC(OMH) - UTC(TP)	-0.07
MAY 22	47668.05	UTC(TAO) - UTC(CRL)	0.08
JUL 25	47732.50	UTC(SU) - UTC(STA)	0.27
OCT 23	47822.53	UTC(TP) - UTC(CH)	-0.86
OCT 26	47825.58	UTC(TP) - UTC(PTB)	-0.89
OCT 27	47826.47	UTC(TP) - UTC(ZIPE)	-1.18
OCT 27	47826.51	UTC(TP) - UTC(ASMW)	-0.78
NOV 15	47845.00	UTC(SU) - UTC(ASMW)	0.0 *
NOV 30	47860.06	UTC(SU) - UTC(PKNM)	0.14
DEC 13	47873.44	UTC(SU) - UTC(OMH)	0.11

* UTC-UTC(SU) of Table 9 is based on this clock transportation.

B - GPS TIME COMPARISONS WITH DIFFERENTIAL CALIBRATION OF RECEIVER DELAYS

DATE 1989	MJD	TIME COMPARISONS	DIFFERENCE GPS COMP. - BIPM (Unit : 1 microsecond)

NONE

TABLE 11 - INTERNATIONAL ATOMIC TIME , BI-MONTHLY RATES OF TAI-CLOCK FOR 1989

THE RATES ARE AVERAGED OVER INTERVALS OF TWO MONTHS ENDING AT THE GIVEN DATES

UNIT IS NS/DAY , *** DENOTES THAT THE CLOCK WAS NOT USED

LAB.	CLOCK		47579	47639	47699	47769	47829	47889
AOS	19	7	***	***	***	135.80	68.09	107.30
APL	40	3101	***	***	***	***	***	3.03
APL	40	3106	***	***	***	***	***	1.96
ASMW	16	76	59.66	53.37	40.18	21.80	20.45	44.94
AUS	12	338	15.76	15.23	17.74	-6.79	-5.43	8.90
AUS	12	590	202.88	198.31	***	***	***	***
AUS	12	1823	3.76	-0.26	-15.99	-27.53	***	***
AUS	14	870	12.26	6.18	-21.69	-33.83	-30.16	-19.60
AUS	14	902	***	***	***	***	***	-66.06
AUS	14	1363	***	-45.11	***	***	***	***
AUS	14	1443	-12.90	-19.92	-22.20	-26.78	-28.25	-25.40
AUS	14	1694	***	-7.69	***	***	24.97	33.11
AUS	14	1777	-157.90	-140.49	-143.96	-149.44	-154.99	-149.08
AUS	14	1844	***	***	***	70.21	80.86	103.79
AUS	14	2010	-44.58	-42.91	-43.75	-49.64	***	***
AUS	44	1	9.69	10.70	13.91	***	17.41	37.00
AUS	44	2	40.63	39.81	40.12	44.00	44.42	25.93
BEV	16	71	-59.13	-65.25	-80.99	-109.62	***	***
CAO	16	183	21.76	26.54	25.73	11.01	6.02	***
CAO	30	384	-3.10	6.39	***	***	***	***
CH	12	285	12.26	6.03	13.69	3.49	12.84	36.38
CH	12	863	-18.42	-27.31	-37.93	-50.75	-46.43	-35.63
CH	16	64	-4.99	1.40	-6.74	-18.52	-6.40	2.68
CH	16	69	-142.30	-139.64	-138.84	-133.94	-134.65	-127.95
CH	16	77	-2.61	-0.52	-3.63	-2.18	0.89	3.31
CH	16	114	22.28	17.14	29.92	-1.53	1.23	41.34
CH	16	140	-0.31	-1.20	-16.95	-41.32	-23.72	-10.32
CH	17	206	-104.99	-106.08	-111.16	-122.51	-141.95	-147.51
CH	21	179	-43.27	-50.40	-57.77	-43.39	-49.23	-40.75
CH	21	194	96.80	93.40	88.71	87.01	84.37	88.12
CH	21	243	24.62	16.43	12.43	5.38	13.02	2.25
CH	21	265	2.89	-9.31	-3.15	-16.57	-14.60	-26.71
CH	31	403	***	***	***	***	-2.05	-3.56
CRL	14	764	***	-45.40	-46.82	-46.67	-50.13	-53.20
CRL	14	865	-97.55	-96.48	-89.51	-84.14	-84.73	-81.94

TABLE 11 - (CONT.)

LAB.	CLOCK	47579	47639	47699	47769	47829	47889
CRL	14 1729	-111.79	-113.15	-113.27	-112.69	-107.66	-110.17
CRL	14 2456	-37.85	-35.58	-32.50	-35.41	-35.25	-46.47
CRL	31 131	***	-30.96	-34.19	-36.14	-40.13	-54.56
CRL	31 305	***	***	***	153.47	153.77	141.75
CRL	45 3	98.52	104.08	103.05	102.85	102.93	108.74
CSAO	12 1646	15.74	14.90	32.21	20.49	22.14	-10.27
CSAO	12 1647	93.45	102.57	137.51	***	***	***
CSAO	12 1648	64.81	75.15	78.68	74.24	75.58	59.16
CSAO	12 2068	***	***	***	***	64.04	108.17
CSAO	30 151	***	***	***	***	247.17	226.78
F	12 206	-276.22	-279.72	-269.43	-234.82	-239.71	-260.14
F	12 347	-83.13	-81.31	-88.36	-92.98	-91.30	-81.00
F	12 439	-169.72	-196.45	-189.47	-185.70	-199.81	-205.94
F	12 2405	***	***	27.04	24.12	6.22	11.68
F	14 134	-29.47	-31.80	-13.39	***	***	***
F	14 158	68.87	70.54	68.27	67.39	68.36	64.09
F	14 195	-102.31	-106.25	-111.61	-111.65	-109.26	-114.19
F	14 405	***	***	***	-14.71	-22.19	-17.93
F	14 500	8.22	7.26	3.40	2.87	-3.53	-6.80
F	14 560	-98.96	-98.99	-101.75	-103.04	-104.22	-98.27
F	14 594	***	***	***	-92.26	-91.60	-84.61
F	14 1120	-62.85	-57.87	-57.01	-56.79	-56.39	-57.46
F	14 1407	-137.63	-136.22	-134.72	***	***	***
F	14 1645	***	-4.02	0.00	-2.40	-5.92	6.30
F	14 1712	-112.39	-109.32	-108.13	-87.02	-97.41	-109.84
F	16 106	8.76	2.26	-5.42	-12.51	-11.63	4.15
F	16 178	-148.79	-168.02	***	***	***	***
F	16 187	-29.32	-28.98	-40.20	-40.54	-35.95	-32.81
F	17 489	16.42	12.47	9.56	16.64	***	***
FTZ	14 312	***	***	14.38	7.86	-6.92	-3.68
FTZ	14 895	19.40	14.99	17.70	19.55	11.88	14.73
FTZ	14 1217	-6.31	-1.25	-1.42	-2.18	-5.06	-2.66
FTZ	14 1482	9.39	11.42	11.68	12.71	12.32	9.94
FTZ	14 1656	-0.21	17.71	17.18	17.18	5.17	7.29
FTZ	14 1674	16.17	15.87	***	***	19.39	14.88
FTZ	16 130	***	24.75	26.64	17.22	28.55	11.23
IEN	14 469	***	-205.51	-204.40	-199.78	-199.80	-205.18
IEN	14 893	-56.25	-65.01	-66.78	-58.39	-50.82	-53.95
IEN	14 1230	-78.75	-69.13	-53.13	-21.63	-23.18	-82.96
IFAG	14 1105	-124.42	-132.98	-129.46	-107.10	-116.62	-122.37

TABLE 11 - (CONT.)

LAB.	CLOCK		47579	47639	47699	47769	47829	47889
IFAG	16	131	***	***	-36.10	-30.20	-51.33	-36.69
IFAG	16	138	50.57	42.32	25.60	14.46	43.58	74.93
IFAG	16	274	176.16	191.02	191.62	187.41	184.35	183.46
INPL	14	2308	82.52	70.97	***	***	***	***
INPL	31	145	-110.49	-116.74	***	***	***	-120.38
KSRI	12	1406	143.12	194.78	295.00	325.29	288.38	281.96
KSRI	12	1902	***	***	***	11.06	10.23	11.85
KSRI	12	1903	-166.49	-148.13	-140.00	-144.45	-146.38	-149.93
KSRI	14	1516	-46.86	-60.09	***	-89.90	-94.19	-100.40
NAOM	14	614	***	***	-80.01	***	***	***
NAOM	14	885	-10.00	-7.94	-5.79	-1.53	6.95	0.95
NAOM	14	1315	-91.23	-84.36	-84.27	-78.65	-82.39	-89.89
NAOM	14	2146	-86.61	-85.49	-87.81	-94.10	-84.56	-82.19
NIM	12	1615	-1170.68	-1360.28	-935.54	-1075.39	***	***
NIM	12	1633	-0.69	12.85	16.01	85.85	***	***
NIM	12	1640	15.39	9.34	4.32	8.39	***	***
NIST	11	167	-0.67	-13.95	-7.69	-7.66	-9.24	-44.84
NIST	11	169	-1158.80	***	***	***	***	***
NIST	12	352	-270.56	-270.68	-246.82	***	***	***
NIST	13	61	-69.24	-90.57	-118.88	-137.99	-120.15	-116.78
NIST	14	323	-189.88	***	***	-14.41	10.13	8.14
NIST	14	601	-24.00	-21.66	-22.39	-22.54	-23.04	-21.46
NIST	14	1316	-107.59	-108.34	-108.79	-106.37	-107.83	-105.60
NIST	14	2165	-13.46	-18.91	-20.66	-14.92	-13.43	-9.72
NIST	14	2315	***	10485.92	10482.84	***	***	***
NIST	16	217	-53.29	-62.14	-23.73	-23.14	-23.14	-29.49
NIST	18	113	-425.43	-438.08	-448.17	-471.55	-483.69	-496.17
NPL	12	316	-130.55	-131.28	-136.04	-137.73	-108.28	-103.76
NPL	12	418	-171.57	-172.06	-158.83	-155.24	-134.36	-137.24
NPL	12	832	***	***	***	***	***	-293.65
NPL	14	1334	-64.90	-74.70	-83.81	-80.38	-95.03	-98.35
NPL	14	1813	***	***	1.54	7.54	7.91	9.35
NPL	14	2064	-2.85	***	***	***	***	-10.08
NPL	31	328	-1.36	-6.91	-0.97	1.47	-5.72	-12.00
NRC	14	267	-73.27	-72.41	-64.66	-51.92	-63.97	-78.17
NRC	90	5	-11.55	-4.02	-10.19	-33.54	-28.36	-30.60
NRC	90	61	-25.42	-20.74	-22.74	-28.78	-31.11	-20.73
NRC	90	63	-18.85	8.76	-16.12	-12.45	-20.59	-9.21
NRLM	12	363	132.60	125.41	117.66	141.46	141.70	141.49
NRLM	14	906	***	***	***	***	***	452.10

TABLE 11 - (CONT.)

LAB.	CLOCK		47579	47639	47699	47769	47829	47889
NRLM	14	1632	-43.35	-46.97	-44.03	-47.18	***	***
NRLM	31	312	98.56	136.15	189.14	237.53	99.93	48.41
OMH	12	1067	-7.60	3.32	-5.20	2.34	-10.05	-2.92
ORB	12	205	-174.35	-184.16	-185.34	-323.19	-377.38	-381.36
ORB	12	804	-92.54	-100.68	-105.21	-77.92	-29.41	-30.69
PEL	12	933	***	***	***	-12.10	***	***
PKNM	16	124	-13.96	-11.23	-15.57	-13.75	-15.92	19.03
PKNM	16	154	-106.27	-97.12	-86.15	***	-87.93	-73.79
PTB	12	320	-58.84	-56.33	-57.35	-54.76	-52.66	-54.09
PTB	14	394	-28.23	-28.55	-24.72	-24.48	-22.66	-27.83
PTB	14	867	-200.23	-199.51	-195.94	-188.95	-180.69	-183.67
PTB	14	1103	-46.24	-47.60	-45.98	-41.46	-47.95	-64.19
PTB	14	2379	-44.51	-46.25	-47.43	-45.27	-46.32	-47.44
PTB	92	1	1.83	1.19	-1.72	-2.53	-2.72	-0.87
PTB	92	2	-1.16	-2.42	-3.55	-4.59	-3.57	-2.91
ROA	14	896	-24.07	-2.47	4.04	11.29	14.34	15.47
ROA	14	1569	-0.60	-1.72	5.05	21.80	-0.50	10.40
ROA	16	121	53.24	44.55	37.13	35.81	37.93	42.44
ROA	16	177	-11.42	-17.57	5.81	-30.72	-8.01	-16.10
SO	12	997	-60.78	-47.44	-71.85	-76.93	-74.59	-71.30
SO	14	574	-53.59	-39.01	-50.93	-11.16	-17.69	-12.73
SO	16	180	54.45	54.28	50.13	59.21	69.90	71.42
STA	14	900	-38.15	-33.11	-45.31	-54.05	-47.05	-43.26
STA	14	1376	-103.50	-106.63	-105.60	-99.33	-96.47	-98.77
STA	16	137	-90.85	-93.47	-90.11	-97.73	-93.15	-93.78
SU	40	381	-16.34	-9.23	-16.74	-20.05	-12.29	-13.20
SU	40	382	-16.38	-9.16	-16.72	-20.18	-12.29	-13.30
TAO	14	390	-82.68	-80.21	***	***	***	***
TAO	14	1075	-35.36	-36.66	-36.28	-35.29	-35.70	-34.89
TAO	14	1498	-158.25	-155.26	-151.25	-147.40	-144.05	-141.71
TAO	14	2494	-8.75	-10.74	-12.83	-14.86	-13.35	-12.55
TAO	31	283	-80.90	-87.31	-92.54	-95.80	***	-45.77
TAO	31	284	-173.57	-166.01	-162.96	-165.06	-169.22	-171.06
TAO	31	285	-53.59	-51.45	-55.13	-55.94	-51.68	-47.20
TAO	31	286	-145.42	-150.79	-154.97	-155.64	-145.11	-139.45
TL	12	477	-126.64	-160.59	-156.92	-184.70	-201.24	-222.67
TL	12	1145	131.33	128.24	118.70	128.52	102.87	125.05
TL	12	2276	-42.17	-44.96	-46.37	-61.70	-63.60	-67.33
TL	16	283	***	-41.23	***	***	***	***
TL	31	317	-47.82	-51.27	-56.48	-56.80	-65.69	-72.62

TABLE 11 - (CONT.)

LAB.	CLOCK	47579	47639	47699	47769	47829	47889
TP	17 101	-125.74	-122.55	-142.05	-165.32	-157.08	-55.21
TUG	12 524	50.65	59.73	69.02	63.17	52.79	45.98
TUG	14 1654	25.30	23.61	25.53	25.74	21.47	23.64
TUG	18 108	487.25	496.47	511.39	536.69	554.71	567.98
USNO	14 116	-100.38	-91.51	-89.12	-73.16	-90.63	-92.16
USNO	14 336	***	***	-74.79	-99.71	-138.63	***
USNO	14 341	***	***	-94.68	***	***	***
USNO	14 444	14.00	***	***	***	***	***
USNO	14 583	-7.81	0.37	19.37	-41.56	-26.76	3.29
USNO	14 653	***	***	***	***	34.55	20.22
USNO	14 656	58.61	54.10	54.05	58.94	60.66	62.88
USNO	14 752	***	***	***	***	36.17	38.04
USNO	14 787	13.54	30.60	43.32	38.91	38.41	13.86
USNO	14 837	***	***	***	***	48.61	42.84
USNO	14 862	142.20	139.79	148.35	146.55	***	***
USNO	14 1028	89.81	45.90	19.91	-20.53	24.53	45.62
USNO	14 1035	***	***	***	***	-71.26	-83.59
USNO	14 1094	-182.94	***	***	***	-111.17	-119.87
USNO	14 1104	-45.67	***	***	***	***	***
USNO	14 1114	-119.99	-117.21	-113.78	***	***	***
USNO	14 1117	-63.84	-60.38	-44.12	-50.59	-55.00	-72.38
USNO	14 1255	-62.04	-58.08	-59.15	-59.85	-57.05	-56.93
USNO	14 1300	-280.33	***	***	***	-33.80	***
USNO	14 1301	-81.85	-100.23	-92.60	-75.14	-77.37	***
USNO	14 1305	-83.67	-77.05	-83.37	-87.52	-84.85	-86.09
USNO	14 1343	***	***	***	***	1461.65	1471.07
USNO	14 1362	14.00	24.79	18.52	26.05	26.36	18.77
USNO	14 1490	***	***	***	***	-143.70	-6.06
USNO	14 1605	36.11	40.19	47.54	50.40	52.81	45.38
USNO	14 1653	***	***	-12.76	-17.71	***	***
USNO	14 1710	-74.06	-69.41	-72.93	-75.26	-69.07	-76.56
USNO	14 1809	-79.16	-75.99	-64.14	-61.19	-64.71	-79.02
USNO	14 1846	***	-67.29	-63.20	-60.16	-56.44	-61.19
USNO	14 2098	-78.62	-80.95	-54.11	***	***	***
USNO	14 2100	-70.50	-76.53	-92.17	***	***	***
USNO	14 2157	***	***	-69.42	***	***	***
USNO	14 2312	-44.25	-28.97	-35.38	-54.53	-41.85	-41.12
USNO	14 2313	***	***	-29.96	-15.15	***	***
USNO	14 2314	-24.58	-21.33	-19.16	-1.69	15.48	1.16
USNO	14 2481	-39.01	-14.56	-8.74	-5.63	-1.93	-5.68

TABLE 11 - (CONT.)

LAB.	CLOCK		47579	47639	47699	47769	47829	47889
USNO	14	2482	-28.29	-23.04	-20.31	1.56	20.06	4.53
USNO	14	2483	-49.67	-48.76	-44.12	-36.85	-34.43	-36.41
USNO	14	2484	-80.54	-87.72	***	***	***	***
USNO	14	2485	-192.13	-202.97	-176.93	-179.97	-191.18	-218.28
USNO	14	2486	-26.98	-22.06	-18.49	-44.74	-41.05	-33.08
USNO	14	2488	-147.25	-128.84	-133.55	-134.70	-132.21	-140.33
USNO	31	218	***	***	-116.82	-140.38	***	***
USNO	31	333	-16.17	-22.40	-25.85	***	***	***
USNO	31	334	46.46	47.36	15.73	***	***	***
USNO	31	335	-26.57	-31.86	-47.79	-37.50	-34.94	-37.39
USNO	31	339	43.94	37.04	34.47	44.90	64.80	50.17
USNO	31	340	-8.50	-15.74	-14.60	-12.46	-7.82	-12.05
USNO	31	342	14.77	-17.27	***	***	***	***
USNO	40	1	***	***	3.72	-3.36	2.91	-32.43
USNO	40	22	-81.28	-32.27	-57.44	-75.26	-89.03	-103.97
USNO	40	23	-56.15	-51.20	-83.03	-89.95	33.36	-8.91
USNO	43	8	-16.25	-12.24	0.94	31.22	-33.24	11.64
VSL	12	349	34.19	26.17	23.69	***	5.95	4.87
VSL	12	1489	-307.70	-325.38	-333.44	-352.72	***	***
VSL	14	1034	-74.42	-81.48	-77.96	-73.19	-75.63	-77.77
VSL	31	288	-35.38	-17.96	-17.91	-27.42	-29.78	-47.88
YUZM	12	1189	-26.14	17.25	70.49	112.42	35.68	-41.65
ZIPE	12	979	-133.96	-131.14	-145.58	-142.14	-138.98	-128.84

The clocks are designated by their type (2 digits) and serial number in the type.

The codes for the types are

11 HEWLETT-PACKARD 5060A
12 HEWLETT-PACKARD 5061A
13 EBAUCHES , OSCILLATOM B5000
14 HEWLETT-PACKARD 5061A OPT.4

16 OSCILLOQUARTZ 3200
17 OSCILLOQUARTZ 3000
18 FREQ. AND TIME SYSTEMS INC. 4000
19 ROHDE AND SCHWARZ XSC

20 FREQ. AND TIME SYSTEMS INC. 5000
21 OSCILLOQUARTZ 3210
25 HEWLETT-PACKARD 5062C
30 HEWLETT-PACKARD 5061B
31 HEWLETT-PACKARD 5061B OPT. 4

4x HYDROGEN MASERS
9x PRIMARY CLOCKS AND PROTOTYPES

TABLE 12 - INTERNATIONAL ATOMIC TIME , WEIGHTS OF THE CLOCKS FOR 1989

THE WEIGHTS ARE GIVEN FOR INTERVALS OF TWO MONTHS ENDING AT THE GIVEN DATES

*** DENOTES THAT THE CLOCK WAS NOT USED

LAB.	CLOCK		47579	47639	47699	47769	47829	47889
AOS	19	7	***	***	***	0	0	0
APL	40	3101	***	***	***	***	***	0
APL	40	3106	***	***	***	***	***	0
ASMW	16	76	1	1	1	4	3	4
AUS	12	338	0	0	100	0	5	8
AUS	12	590	0	5	***	***	***	***
AUS	12	1823	4	4	7	6	***	***
AUS	14	870	7	14	0	3	2	3
AUS	14	902	***	***	***	***	***	0
AUS	14	1363	***	0	***	***	***	***
AUS	14	1443	27	54	69	40	29	29
AUS	14	1694	***	0	***	***	0	0
AUS	14	1777	21	21	22	25	21	23
AUS	14	1844	***	***	***	0	0	2
AUS	14	2010	100	100	100	80	***	***
AUS	44	1	100	78	54	***	0	0
AUS	44	2	100	100	100	100	100	0
BEV	16	71	14	15	9	0	***	***
CAO	16	183	7	7	7	7	7	***
CAO	30	384	0	6	***	***	***	***
CH	12	285	0	0	30	26	38	0
CH	12	863	6	5	7	6	6	7
CH	16	64	13	16	19	18	20	17
CH	16	69	0	0	100	62	77	41
CH	16	77	57	90	100	100	100	100
CH	16	114	0	9	6	6	6	4
CH	16	140	2	2	3	3	4	4
CH	17	206	100	100	100	0	0	3
CH	21	179	42	43	32	29	34	26
CH	21	194	100	92	54	52	35	45
CH	21	243	5	4	5	9	24	15
CH	21	265	46	17	16	14	12	9
CH	31	403	***	***	***	***	0	0
CRL	14	764	***	0	0	100	100	75
CRL	14	865	100	100	56	23	21	24

TABLE 12 - (CONT.)

LAB.	CLOCK	47579	47639	47699	47769	47829	47889
CRL	14 1729	31	57	100	100	100	100
CRL	14 2456	14	23	34	82	100	0
CRL	31 131	***	0	0	62	40	0
CRL	31 305	***	***	***	0	0	0
CRL	45 3	12	12	14	23	56	99
CSAO	12 1646	2	2	2	3	21	0
CSAO	12 1647	1	2	2	***	***	***
CSAO	12 1648	10	9	11	21	46	17
CSAO	12 2068	***	***	***	***	0	0
CSAO	30 151	***	***	***	***	0	0
F	12 206	3	4	4	3	3	3
F	12 347	0	0	37	22	30	35
F	12 439	9	3	3	5	6	6
F	12 2405	***	***	0	0	0	7
F	14 134	16	11	11	***	***	***
F	14 158	0	78	100	100	100	100
F	14 195	100	100	81	55	56	50
F	14 405	***	***	***	0	0	35
F	14 500	0	82	54	56	33	27
F	14 560	0	100	100	100	100	100
F	14 594	***	***	***	0	0	27
F	14 1120	0	77	100	100	100	100
F	14 1407	100	74	55	***	***	***
F	14 1645	***	0	0	100	94	37
F	14 1712	100	100	100	0	10	11
F	16 106	0	0	10	8	10	13
F	16 178	9	10	***	***	***	***
F	16 187	22	52	29	31	31	37
F	17 489	0	0	42	62	***	***
FTZ	14 312	***	***	0	0	4	7
FTZ	14 895	100	100	100	100	100	100
FTZ	14 1217	13	21	100	100	100	100
FTZ	14 1482	5	100	100	100	100	100
FTZ	14 1656	13	15	13	15	15	17
FTZ	14 1674	100	100	***	***	0	0
FTZ	16 130	***	0	0	18	26	15
IEN	14 469	***	0	0	65	87	100
IEN	14 893	0	12	14	24	25	27
IEN	14 1230	2	2	2	2	2	1
IFAG	14 1105	27	19	20	0	12	12

TABLE 12 - (CONT.)

LAB.	CLOCK		47579	47639	47699	47769	47829	47889
IFAG	16	131	***	***	0	0	4	8
IFAG	16	138	3	2	2	4	6	2
IFAG	16	274	12	22	15	14	16	30
INPL	14	2308	0	0	***	***	***	***
INPL	31	145	34	52	***	***	***	0
KSRI	12	1406	0	3	0	0	0	0
KSRI	12	1902	***	***	***	0	0	100
KSRI	12	1903	0	6	5	8	12	12
KSRI	14	1516	5	9	***	0	0	18
NAOM	14	614	***	***	0	***	***	***
NAOM	14	885	24	24	25	31	0	27
NAOM	14	1315	23	23	24	29	45	47
NAOM	14	2146	85	100	100	86	70	60
NIM	12	1615	0	0	0	0	***	***
NIM	12	1633	16	18	19	0	***	***
NIM	12	1640	8	8	13	13	***	***
NIST	11	167	0	6	7	9	17	0
NIST	11	169	1	***	***	***	***	***
NIST	12	352	8	7	7	***	***	***
NIST	13	61	0	0	1	1	1	2
NIST	14	323	100	***	***	0	0	3
NIST	14	601	72	100	100	100	100	100
NIST	14	1316	100	94	100	100	100	100
NIST	14	2165	37	34	50	50	53	67
NIST	14	2315	***	0	0	***	***	***
NIST	16	217	22	14	5	4	3	3
NIST	18	113	6	5	4	2	2	1
NPL	12	316	16	12	20	74	0	5
NPL	12	418	18	25	26	18	0	4
NPL	12	832	***	***	***	***	***	0
NPL	14	1334	11	6	4	5	5	6
NPL	14	1813	***	***	0	0	46	63
NPL	14	2064	100	***	***	***	***	0
NPL	31	328	14	19	29	68	66	40
NRC	14	267	6	5	7	11	17	12
NRC	90	5	3	4	4	6	6	6
NRC	90	61	7	12	31	42	36	51
NRC	90	63	10	6	6	6	6	9
NRLM	12	363	4	8	19	10	8	10
NRLM	14	906	***	***	***	***	***	0

TABLE 12 - (CONT.)

LAB.	CLOCK		47579	47639	47699	47769	47829	47889
NRLM	14	1632	10	14	38	74	***	***
NRLM	31	312	0	0	0	0	0	0
OMH	12	1067	0	0	15	24	23	35
ORB	12	205	18	10	9	0	0	0
ORB	12	804	43	0	15	11	0	1
PEL	12	933	***	***	***	0	***	***
PKNM	16	124	4	4	4	4	4	0
PKNM	16	154	4	3	3	***	0	0
PTB	12	320	79	59	54	100	100	100
PTB	14	394	56	60	62	100	100	100
PTB	14	867	17	15	18	32	0	15
PTB	14	1103	8	10	14	32	100	0
PTB	14	2379	100	100	100	100	100	100
PTB	92	1	100	100	100	100	100	100
PTB	92	2	100	100	100	100	100	100
ROA	14	896	31	16	8	5	4	5
ROA	14	1569	15	34	84	0	13	12
ROA	16	121	0	16	20	22	22	23
ROA	16	177	2	4	0	6	7	7
SO	12	997	3	2	2	3	8	8
SO	14	574	4	4	5	3	3	3
SO	16	180	32	31	45	82	0	13
STA	14	900	0	4	4	4	8	18
STA	14	1376	0	0	100	73	51	66
STA	16	137	100	63	61	32	46	100
SU	40	381	0	0	0	0	0	0
SU	40	382	0	0	0	0	0	0
TAO	14	390	34	44	***	***	***	***
TAO	14	1075	48	100	100	100	100	100
TAO	14	1498	51	38	22	16	23	26
TAO	14	2494	100	100	100	100	100	100
TAO	31	283	9	38	29	19	***	0
TAO	31	284	0	35	31	47	68	62
TAO	31	285	25	21	16	17	100	100
TAO	31	286	3	2	2	4	36	25
TL	12	477	0	0	0	0	0	1
TL	12	1145	36	37	13	15	0	9
TL	12	2276	0	12	14	12	11	8
TL	16	283	***	0	***	***	***	***
TL	31	317	0	7	12	18	16	11

TABLE 12 - (CONT.)

LAB.	CLOCK		47579	47639	47699	47769	47829	47889
TP	17	101	0	10	4	2	2	0
TUG	12	524	0	50	29	28	22	13
TUG	14	1654	100	100	100	100	100	100
TUG	18	108	0	0	1	1	1	1
USNO	14	116	9	9	10	8	13	13
USNO	14	336	***	***	0	0	0	***
USNO	14	341	***	***	0	***	***	***
USNO	14	444	0	***	***	***	***	***
USNO	14	583	2	3	3	2	2	2
USNO	14	653	***	***	***	***	0	0
USNO	14	656	0	0	73	100	100	88
USNO	14	752	***	***	***	***	0	0
USNO	14	787	10	8	0	7	7	6
USNO	14	837	***	***	***	***	0	0
USNO	14	862	36	53	60	77	***	***
USNO	14	1028	3	2	1	1	1	1
USNO	14	1035	***	***	***	***	0	0
USNO	14	1094	7	***	***	***	0	0
USNO	14	1104	3	***	***	***	***	***
USNO	14	1114	23	26	32	***	***	***
USNO	14	1117	30	27	16	18	20	10
USNO	14	1255	0	100	100	100	100	100
USNO	14	1300	30	***	***	***	0	***
USNO	14	1301	0	3	5	6	9	***
USNO	14	1305	0	0	36	33	51	69
USNO	14	1343	***	***	***	***	0	0
USNO	14	1362	2	2	3	3	8	41
USNO	14	1490	***	***	***	***	0	0
USNO	14	1605	26	42	45	37	24	27
USNO	14	1653	***	***	0	0	***	***
USNO	14	1710	0	0	85	93	100	100
USNO	14	1809	14	22	18	16	17	15
USNO	14	1846	***	0	0	44	35	58
USNO	14	2098	0	3	3	***	***	***
USNO	14	2100	0	0	4	***	***	***
USNO	14	2157	***	***	0	***	***	***
USNO	14	2312	3	2	1	2	7	13
USNO	14	2313	***	***	0	0	***	***
USNO	14	2314	20	15	18	6	3	4
USNO	14	2481	0	11	9	7	5	6

TABLE 12 - (CONT.)

LAB.	CLOCK	47579	47639	47699	47769	47829	47889
USNO	14 2482	27	37	38	0	3	3
USNO	14 2483	75	59	60	41	28	24
USNO	14 2484	4	5	***	***	***	***
USNO	14 2485	11	8	8	8	9	4
USNO	14 2486	29	23	17	10	8	9
USNO	14 2488	0	0	5	11	17	23
USNO	31 218	***	***	0	0	***	***
USNO	31 333	0	11	10	***	***	***
USNO	31 334	6	11	0	***	***	***
USNO	31 335	0	11	13	16	17	20
USNO	31 339	5	7	11	49	0	9
USNO	31 340	13	12	14	13	55	100
USNO	31 342	0	1	***	***	***	***
USNO	40 1	***	***	0	0	0	0
USNO	40 22	0	0	0	0	0	0
USNO	40 23	0	0	0	0	0	0
USNO	43 8	0	0	0	0	0	0
VSL	12 349	7	5	6	***	0	0
VSL	12 1489	5	3	2	1	***	***
VSL	14 1034	100	100	100	87	100	100
VSL	31 288	2	2	2	3	5	8
YUZM	12 1189	1	1	1	0	0	0
ZIPE	12 979	1	1	3	23	34	23

The clocks are designated by their type (2 digits) and serial number in the type.

11 HEWLETT-PACKARD 5060A
12 HEWLETT-PACKARD 5061A
13 EBAUCHES , OSCILLATOM B5000
14 HEWLETT-PACKARD 5061A OPT.4

16 OSCILLOQUARTZ 3200
17 OSCILLOQUARTZ 3000
18 FREQ. AND TIME SYSTEMS INC. 4000
19 ROHDE AND SCHWARZ XSC

20 FREQ. AND TIME SYSTEMS INC. 5000
21 OSCILLOQUARTZ 3210
25 HEWLETT-PACKARD 5062C
30 HEWLETT-PACKARD 5061B
31 HEWLETT-PACKARD 5061B OPT. 4

4x HYDROGEN MASERS
9x PRIMARY CLOCKS AND PROTOTYPES

TABLE 13 - MEASUREMENTS OF THE EAL AND TAI FREQUENCY

GRAVITATIONAL FREQUENCY CORRECTIONS ARE APPLIED . THE FREQUENCIES ARE EXPRESSED AT SEA LEVEL .

f(EAL) - f(STANDARD) IN 10**-13

INTERVAL MJD	CENTRAL DATE	NRC CsV	NRC CsVIA	NRC CsVIB	NRC CsVIC	PTB CS1	PTB CS2
45699-45759	1984 JAN 30	8.58	8.50	8.36	8.23	8.59	
45759-45819	1984 MAR 30	8.49	8.43	8.21	8.26	8.65	
45819-45879	1984 MAY 29	-	5.78	7.41	7.38	8.43	
45879-45939	1984 JUL 28	7.18	7.30	6.84	6.57	7.91	
45939-45999	1984 SEP 26	7.04	7.45	8.08	6.38	8.19	
45999-46059	1984 NOV 25	6.40	7.07	8.20	6.95	8.43	
46059-46119	1985 JAN 24	7.19	8.81	8.45	7.72	8.66	
46119-46179	1985 MAR 25	7.51	7.52	8.05	7.82	8.19	
46179-46239	1985 MAY 24	8.27	8.03	6.52	8.17	8.36	
46239-46299	1985 JUL 23	8.47	8.04	7.03	7.08	8.17	
46299-46369	1985 SEP 26	8.58	6.86	7.55	7.03	7.93	
46369-46429	1985 NOV 30	8.47	9.22	9.90	6.74	8.57	
46429-46489	1986 JAN 29	8.70	8.93	9.69	8.21	8.58	
46489-46549	1986 MAR 30	8.62	8.68	9.62	8.16	8.36	
46549-46609	1986 MAY 29	8.81	8.39	8.78	8.63	8.05	
46609-46669	1986 JUL 28	8.11	9.25	9.02	8.80	7.85	
46669-46729	1986 SEP 26	8.05	9.77	9.35	9.17	8.02	7.61
46729-46789	1986 NOV 25	8.56	8.53	8.99	8.79	8.06	7.85
46789-46849	1987 JAN 24	7.99	8.01	9.18	8.90	8.18	7.98
46849-46909	1987 MAR 25	8.33	8.13	8.41	8.65	8.36	7.91
46909-46969	1987 MAY 24	7.03	7.46	8.70	8.26	7.99	7.69
46969-47029	1987 JUL 23	6.40	7.01	8.38	7.00	8.20	7.64
47029-47099	1987 SEP 26	6.50	7.79	7.55	6.43	7.82	7.68
47099-47159	1987 NOV 30	7.11	8.78	10.48	6.87	8.04	7.79
47159-47219	1988 JAN 29	9.71	10.70	-	8.18	7.97	7.85
47219-47279	1988 MAR 29	8.56	7.78	-	7.48	8.16	7.79
47279-47339	1988 MAY 28	8.16	7.16	-	7.59	8.11	7.76
47339-47399	1988 JUL 27	9.14	5.98	-	7.39	7.80	7.64
47399-47459	1988 SEP 25	4.47	4.91	-	7.22	7.82	7.62
47459-47519	1988 NOV 24	4.79	4.13	-	4.77	7.87	7.76
47519-47579	1989 JAN 23	6.77	5.17	-	5.93	8.21	7.87
47579-47639	1989 MAR 24	7.64	5.71	-	9.12	8.14	7.72
47639-47699	1989 MAY 23	6.93	5.48	-	6.24	7.80	7.59
47699-47769	1989 JUL 27	4.18	4.73	-	6.62	7.66	7.42
47769-47829	1989 SEP 30	4.78	4.46	-	5.68	7.64	7.54
47829-47889	1989 NOV 29	4.52	5.66	-	6.99	7.85	7.61

TABLE 13 - (CONT.)

f(EAL) - f(STANDARD) IN 10**-13

INTERVAL MJD	CENTRAL DATE	CRL CS1	NIST NIST6	SU MCsR 101	SU MCsR 102
45702-45722	1984 JAN 13			6.02	
45789-45849	1984 APR 29	6.45			
45794-45836	1984 APR 25			6.74	
45889-45949	1984 AUG 17		7.24		
45949-45967	1984 SEP 15				6.22
45959-46019	1984 OCT 16		7.70		
45983-46004	1984 OCT 21				5.93
45999-46059	1984 NOV 25	7.53			
46005-46034	1984 NOV 16				6.12
46054-46059	1984 DEC 23				6.37
46079-46139	1985 FEB 13	7.54			
46080-46096	1985 JAN 23				6.14
46100-46110	1985 FEB 9				5.78
46156-46159	1985 APR 3				6.23
46201-46216	1985 MAY 24			5.87	
46230-46244	1985 JUN 21			7.04	
46247-46277	1985 JUL 16			6.39	
46279-46300	1985 AUG 13			5.75	
46312-46335	1985 SEP 16			6.84	
46339-46367	1985 OCT 15			5.90	
46370-46381	1985 NOV 7			5.83	
46502-46516	1986 MAR 20				5.87
46509-46569	1986 APR 19	7.22			
46521-46543	1986 APR 12				5.61
46563-46580	1986 MAY 22				5.76
46585-46600	1986 JUN 11				5.28
46684-46732	1986 OCT 5			5.99	
46737-46762	1986 NOV 16			5.58	
46773-46794	1986 DEC 19				5.35
46801-46816	1987 JAN 14				5.06
46859-46919	1987 APR 5	8.73			
46886-46914	1987 APR 14			5.37	
46919-46941	1987 MAY 15			5.67	
46947-46976	1987 JUN 15			6.11	
46959-47019	1987 JUL 13		9.65		
46977-46998	1987 JUL 11			6.09	
47061-47063	1987 SEP 24			5.59	
47083-47097	1987 OCT 21				5.76
47098-47124	1987 NOV 13				5.76
47130-47150	1987 DEC 11				5.36
47164-47173	1988 JAN 9				5.37
47215-47222	1988 FEB 28			5.45	
47256-47278	1988 APR 16				5.87
47286-47288	1988 MAY 6				5.67
47354-47361	1988 JUL 16				5.77
47416-47433	1988 SEP 20				5.57
47437-47439	1988 OCT 4				5.64

TABLE 13 - (CONT.)

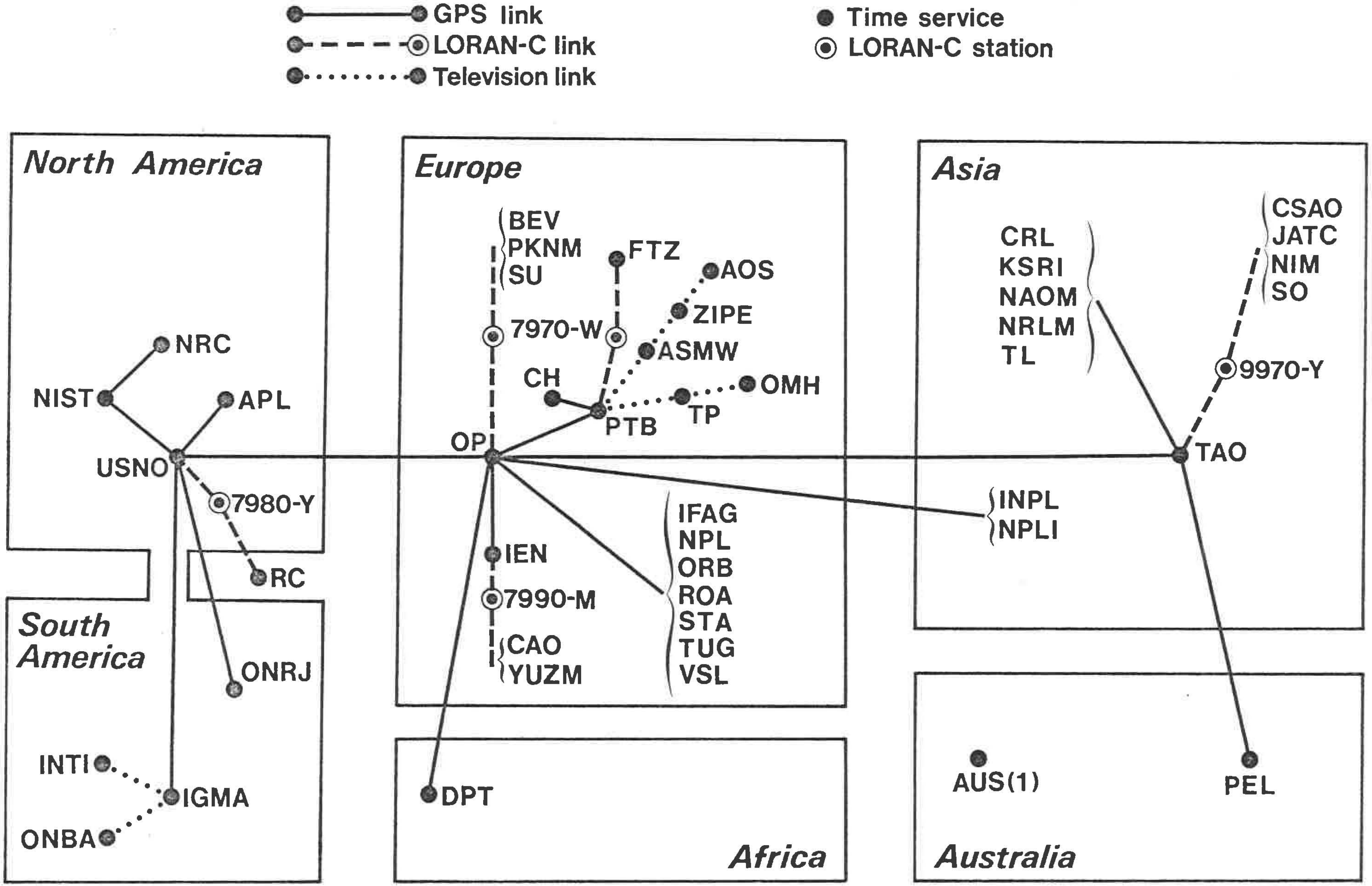
INTERVAL MJD	CENTRAL DATE	f(TAI) - f(STANDARD) IN 10**-13					
		NRC CsV	NRC CsVIA	NRC CsVIB	NRC CsVIC	PTB CS1	PTB CS2
45699-45759	1984 JAN 30	0.78	0.70	0.56	0.43	0.79	
45759-45819	1984 MAR 30	0.49	0.43	0.21	0.26	0.65	
45819-45879	1984 MAY 29	-	-2.22	-0.59	-0.62	0.43	
45879-45939	1984 JUL 28	-0.82	-0.70	-1.16	-1.43	-0.09	
45939-45999	1984 SEP 26	-0.96	-0.55	0.08	-1.62	0.19	
45999-46059	1984 NOV 25	-1.60	-0.93	0.20	-1.05	0.43	
46059-46119	1985 JAN 24	-0.81	0.81	0.45	-0.28	0.66	
46119-46179	1985 MAR 25	-0.49	-0.48	0.05	-0.18	0.19	
46179-46239	1985 MAY 24	0.27	0.03	-1.48	0.18	0.36	
46239-46299	1985 JUL 23	0.47	0.04	-0.97	-0.92	0.17	
46299-46369	1985 SEP 26	0.58	-1.14	-0.45	-0.97	-0.07	
46369-46429	1985 NOV 30	0.47	1.22	1.90	-1.26	0.57	
46429-46489	1986 JAN 29	0.70	0.93	1.69	0.21	0.58	
46489-46549	1986 MAR 30	0.62	0.68	1.62	0.16	0.36	
46549-46609	1986 MAY 29	0.81	0.39	0.78	0.63	0.05	
46609-46669	1986 JUL 28	0.11	1.25	1.02	0.80	-0.15	
46669-46729	1986 SEP 26	0.05	1.77	1.35	1.17	0.02	-0.39
46729-46789	1986 NOV 25	0.56	0.53	0.99	0.79	0.06	-0.15
46789-46849	1987 JAN 24	-0.02	0.00	1.17	0.89	0.17	-0.04
46849-46909	1987 MAR 25	0.32	0.12	0.40	0.64	0.35	-0.10
46909-46969	1987 MAY 24	-0.99	-0.55	0.69	0.25	-0.03	-0.32
46969-47029	1987 JUL 23	-1.61	-1.01	0.37	-1.01	0.19	-0.37
47029-47099	1987 SEP 26	-1.51	-0.22	-0.46	-1.58	-0.19	-0.34
47099-47159	1987 NOV 30	-0.91	0.77	2.46	-1.14	0.02	-0.23
47159-47219	1988 JAN 29	1.71	2.70	-	0.18	-0.03	-0.15
47219-47279	1988 MAR 29	0.56	-0.22	-	-0.52	0.16	-0.21
47279-47339	1988 MAY 28	0.16	-0.84	-	-0.41	0.11	-0.24
47339-47399	1988 JUL 27	1.14	-2.02	-	-0.61	-0.20	-0.36
47399-47459	1988 SEP 25	-3.53	-3.09	-	-0.78	-0.18	-0.38
47459-47519	1988 NOV 24	-3.21	-3.87	-	-3.23	-0.13	-0.24
47519-47579	1989 JAN 23	-1.23	-2.83	-	-2.07	0.21	-0.13
47579-47639	1989 MAR 24	-0.36	-2.29	-	1.12	0.14	-0.28
47639-47699	1989 MAY 23	-1.07	-2.52	-	-1.76	-0.20	-0.41
47699-47769	1989 JUL 27	-3.77	-3.22	-	-1.33	-0.29	-0.53
47769-47829	1989 SEP 30	-3.17	-3.49	-	-2.27	-0.31	-0.41
47829-47889	1989 NOV 29	-3.43	-2.29	-	-0.96	-0.10	-0.34

TABLE 13 - (CONT.)

INTERVAL MJD	CENTRAL DATE	CRL CS1	NIST NIST6	SU MCsR 101	SU MCsR 102
		f(TAI) - f(STANDARD) IN 10**-13			
45702-45722	1984 JAN 13			-1.78	
45789-45849	1984 APR 29	-1.55			
45794-45836	1984 APR 25			-1.26	
45889-45949	1984 AUG 17		-0.76		
45949-45967	1984 SEP 15				-1.78
45959-46019	1984 OCT 16		-0.30		
45983-46004	1984 OCT 21				-2.07
45999-46059	1984 NOV 25	-0.47			
46005-46034	1984 NOV 16				-1.88
46054-46059	1984 DEC 23				-1.63
46079-46139	1985 FEB 13	-0.46			
46080-46096	1985 JAN 23				-1.86
46100-46110	1985 FEB 9				-2.22
46156-46159	1985 APR 3				-1.77
46201-46216	1985 MAY 24			-2.13	
46230-46244	1985 JUN 21			-0.96	
46247-46277	1985 JUL 16			-1.61	
46279-46300	1985 AUG 13			-2.25	
46312-46335	1985 SEP 16			-1.16	
46339-46367	1985 OCT 15			-2.10	
46370-46381	1985 NOV 7			-2.17	
46502-46516	1986 MAR 20				-2.13
46509-46569	1986 APR 19	-0.78			
46521-46543	1986 APR 12				-2.39
46563-46580	1986 MAY 22				-2.24
46585-46600	1986 JUN 11				-2.72
46684-46732	1986 OCT 5			-2.01	
46737-46762	1986 NOV 16			-2.42	
46773-46794	1986 DEC 19				-2.65
46801-46816	1987 JAN 14				-2.94
46859-46919	1987 APR 5	0.73			
46886-46914	1987 APR 14			-2.64	
46919-46941	1987 MAY 15			-2.34	
46947-46976	1987 JUN 15			-1.09	
46959-47019	1987 JUL 13		1.64		
46977-46998	1987 JUL 11			-1.92	
47061-47063	1987 SEP 24			-2.42	
47083-47097	1987 OCT 21				-2.26
47098-47124	1987 NOV 13				-2.26
47130-47150	1987 DEC 11				-2.66
47164-47173	1988 JAN 9				-2.63
47215-47222	1988 FEB 28			-2.55	
47256-47278	1988 APR 16				-2.13
47286-47288	1988 MAY 6				-2.33
47354-47361	1988 JUL 16				-2.23
47416-47433	1988 SEP 20				-2.43
47437-47439	1988 OCT 4				-2.36

TABLE 14 - MEAN DURATION OF THE TAI SCALE INTERVAL IN SI SECOND AT SEA LEVEL.

FOR THE MONTHS	MEAN DURATION	UNCERTAINTY (one sigma)
1983 JAN - FEB	1 - 1*10**-14	4*10**-14
1983 MAR - APR	- 2	4
1983 MAY - JUN	- 1	4
1983 JUL - AUG	+ 1	4
1983 SEP - OCT	+ 1	4
1983 NOV - DEC	+ 0	4
1984 JAN - FEB	1 - 2*10**-14	4*10**-14
1984 MAR - APR	- 0	4
1984 MAY - JUN	+ 2	4
1984 JUL - AUG	+ 3	4
1984 SEP - OCT	+ 4	4
1984 NOV - DEC	+ 3	4
1985 JAN - FEB	1 + 0.9*10**-14	2.1*10**-14
1985 MAR - APR	+ 1.8	2.0
1985 MAY - JUN	+ 1.3	2.0
1985 JUL - AUG	+ 1.3	2.0
1985 SEP - OCT	+ 0.8	2.0
1985 NOV - DEC	- 1.6	2.0
1986 JAN - FEB	1 - 2.9*10**-14	2.0*10**-14
1986 MAR - APR	- 2.2	2.0
1986 MAY - JUN	- 0.9	1.9
1986 JUL - AUG	+ 0.4	1.9
1986 SEP - OCT	+ 2.1	1.3
1986 NOV - DEC	+ 0.6	1.3
1987 JAN - FEB	1 - 0.4*10**-14	1.3*10**-14
1987 MAR - APR	- 0.1	1.3
1987 MAY - JUN	+ 2.1	1.3
1987 JUL - AUG	+ 2.6	1.3
1987 SEP - OCT	+ 2.7	1.3
1987 NOV - DEC	+ 1.5	1.3
1988 JAN - FEB	1 + 0.9*10**-14	1.3*10**-14
1988 MAR - APR	+ 1.0	1.3
1988 MAY - JUN	+ 1.5	1.3
1988 JUL - AUG	+ 2.6	1.3
1988 SEP - OCT	+ 3.0	1.3
1988 NOV - DEC	+ 2.6	1.3
1989 JAN - FEB	1 + 0.8*10**-14	1.3*10**-14
1989 MAR - APR	+ 1.9	1.3
1989 MAY - JUN	+ 3.5	1.3
1989 JUL - AUG	+ 4.5	1.3
1989 SEP - OCT	+ 3.8	1.3
1989 NOV - DEC	+ 3.0	1.3



Time links used by the BIPM (end 1989)
(1) GPS link to USNO through Hawaii

fig.1

PART C

TIME SIGNALS (1990)

The time signal emissions reported thereafter follow the UTC system, in accordance with the Recommendation 460-4 of the International Radio Consultative Committee (CCIR), unless otherwise stated.

Their maximum departure from the Universal Time UT1 is thus 0.9 second.

The following tables are based on information received at BIPM in February and March 1990, except in the cases indicated by a note.

AUTHORITIES RESPONSIBLE FOR THE TIME SIGNAL EMISSIONS

Signal	Authority
ATA	National Physical Laboratory Dr K.S. Krishnan Road New Delhi - 110012, India
BPM	Shaanxi Astronomical Observatory Academia Sinica P.O. Box 18 - Lintong Shaanxi, China
BSF	Telecommunication Laboratories Directorate General of Telecommunications Ministry of Communications P.O. Box 71 - Chung-Li 32099 Taiwan, R.O.C.
CHU	National Research Council, Time and Length Standards Section Physics Division (M-36) Ottawa K1A 0R6, Ontario, Canada Attn : Dr. J. Vanier
DCF77	Physikalisch-Technische Bundesanstalt, Lab. Zeiteinheit Bundesallee 100 D-3300 Braunschweig Federal Republic of Germany
DGI, Y3S	Amt für Standardisierung, Messwesen und Warenprüfung Zeit - und Frequenzdienst der DDR Fürstenwalder Damm 388 DDR 1162 Berlin
EBC	Real Instituto y Observatorio de la Armada San Fernando Cadiz, Spain

Signal	Authority
HBG	Service horaire HBG Observatoire Cantonal CH - 2000 Neuchâtel, Suisse
HLA	Time and Frequency Laboratory Korea Standards Research Institute P. O. Box 3, Taedok Science Town Taejon 305-606 Republic of Korea
IAM	Istituto Superiore delle Poste e delle Telecomunicazioni Ufficio 8°, Rep.2° - Viale Europa 190 00144 - Roma, Italy
IBF	Istituto Elettrotecnico Nazionale Galileo Ferraris Strada delle Cacce, 91 10135 - Torino, Italy
JJY, JG2AS	Standards and Measurements Division Communications Research Laboratory Ministry of Posts and Telecommunications Koganei, Tokyo 184, Japan
LOL	Director Observatorio Naval Av. Espana 2099 1107 - Buenos-Aires, Republica Argentina
MSF	National Physical Laboratory Electrical Science Division Teddington, Middlesex TW11 OLW United Kingdom

Signal	Authority
OLB5, OMA	1/ Time information : Astronomický ústav ČSAV, Budečská 6 120 23 Praha 2, Vinohrady, Czechoslovakia. TELEX : 122 486 2/ Standard frequency information : Ústav radiotechniky a elektroniky ČSAV, Lumumbova 1, 182 51 Praha 8, Kobylisy, Czechoslovakia. TELEX : 122 646
PPE, PPR	Departemento Serviço da hora Observatorio Nacional (CNPq) Rua General Bruce, 586 20921 Rio de Janeiro - RJ, Brasil
RBU, RCH, RID, RTA, RTZ, RWM, UNW3, UPD8, UQC3, USB2, UTR3	VNIIFTRI Mendeleevo Moscow Region 141570 USSR
TDF	Centre National d'Etudes des Télécommunications PAB - STC - Etalons de fréquence et de temps 196 avenue Henri Ravera - 92220 Bagneux, France
WWV,WWVH WWVB	Time and Frequency Division, 576.00 National Institute of Standards and Technology 325 Broadway Boulder, Colorado 80303, U.S.A.
YVTO	Direccion de Hidrografia y Navegacion Observatori Cagigal Apartado Postal No 6745 Caracas, Venezuela
Y3S	See DGI

TIME - SIGNALS EMITTED IN THE UTC SYSTEM

Station	Location Latitude Longitude	Frequency (kHz)	Schedule (UTC)	Form of time signals
ATA	Greater Kailash New Delhi India 28° 34'N 77° 19'E	5 000 10 000 15 000	12 h 30 m to 3 h 30 m continuous 3 h 30 m to 12 h 30 m	Second pulses of 5 cycles of a 1 kHz modulation. Minute pulses of 100 ms duration. (the time signals are advanced by 50 ms on UTC).
BPM	Pucheng China 35° 0'N 109° 31'E	2 500 5 000 10 000 15 000	7 h 30 m to 1 h continuous continuous 1 h to 9 h	UTC time signals (the signals are emitted in advance on UTC by 20 ms). Second pulses of 10 ms of 1 kHz modulation. Minute pulses of 300 ms of 1 kHz modulation. From minutes 0 to 10, 15 to 25, 30 to 40, 45 to 55. UT1 time signals are emitted from minutes 25 to 29, 55 to 59.
BSF	Chung-Li Taiwan ROC 24° 57'N 121° 9'E	5 000 15 000	continuous except interruption between minutes 35 and 40	(a) From min. 5 to 10, 15 to 20, 25 to 30, 45 to 50, 55 to 60, second pulses of 5 ms duration without 1 kHz modulation. (b) From min. 0 to 5, 10 to 15, ..., 50 to 55, second pulses of 5 ms duration with 1 kHz modulation. The 1 kHz modulation is interrupted 40 ms before and after the pulses. (c) Minute pulses are extended to 300 ms. (d) DUT1, CCIR code by lengthening.
CHU	Ottawa Canada 45° 18'N 75° 45'W	3 330 7 335 14 670	continuous	Second pulses of 300 cycles of a 1 kHz modulation, with 29th and 51st to 59th pulses of each minute omitted. Minute pulses are 0.5 s long. Hour pulses are 1.0 s long, with the following 1st to 10th pulses omitted. A bilingual (Fr. Eng.) announcement of time (UTC) is made each minute following the 50th second pulse. FSK time code after 10 cycles of 1 kHz on the 31st to 39th seconds. Broadcast is single sideband; upper sideband with carrier reinsert. DUT1 : CCIR code by split pulses.
DCF77	Mainflingen Germany, F.R. 50° 1'N 9° 0'E	77.5	continuous	At the beginning of each second (except the 59th second) the carrier amplitude is reduced to about 25 % for a duration of 0.1 s or 0.2 s. Coded transmission of year, month, day, hour, minute and day of the week in a BCD code from second marker No 21 to No 58 (the second marker durations of 0.1 s or 0.2 s correspond to a binary 0 or a binary 1 respectively). The coded time information is related to legal time of FRG and second markers 17 and 18 indicate if the transmitted time refers to UTC(PTB) + 2 h (summer time) or UTC(PTB) + 1 h. Second marker No 15 is prolonged to 0.2 s, if the reserve antenna is in use. To achieve a more accurate time transfer and better use of the frequency spectrum available, an additional pseudo random phase - shift keying of the carrier is superimposed to the AM second markers. No transmission of DUT1.
DGI	Oranienburg Germ.Dem.Rep. 52° 48'N 13° 24'E	182	5 h 59 m 30 s to 6 h 00, 11 h 59 m 30 s to 12 h 00, 17 h 59 m 30 s to 18 h 00	A2 type second pulses of 0.1 s duration for seconds 30-40, 45-50, 55-60. The last pulse is prolonged. (one hour earlier in summer time)

Station	Location Latitude Longitude	Frequency (kHz)	Schedule (UTC)	Form of time signals
EBC	San Fernando Spain 36° 28'N 6° 12'W	12 008 6 840	10 h 00 m to 10 h 25 m 10 h 30 m to 10 h 55 m	Second pulses of 0.1 s duration of a 1 kHz modulation. Minute pulses of 0.5 s duration of 1 250 Hz modulation. DUT1. CCIR code, double pulse. Type A3H.
HBG	Prangins Switzerland 46° 24'N 6° 15'E	75	continuous	Interruption of the carrier at the beginning of each second, during 100 ms. The minutes are identified by a double pulse, the hours by a triple pulse. No transmission of DUT1. Time code and other coded information.
HLA	Taedok Science Town Republic of Korea 36° 23'N 127° 22'E	5 000	1 h to 8 h on Monday to Friday (Except National Holidays in Korea)	Pulses of 9 cycles of 1800 Hz modulation. 59th and 29th second pulses omitted. Hour identified by 0.8 second long 1500 Hz tone. Beginning of each minute identified by 0.8 second long 1800 Hz tone. Voice announcement of hours and minutes each minute following 52nd second pulse. BCD time code given on 100 Hz subcarrier. DUT1 : CCIR code by double pulse.
IAM	Rome Italy 41° 47'N 12° 27'E	5 000	7 h 30 m to 8 h 30 m 10 h 30 m to 11 h 30 m Except Sunday and National Holidays	Second pulses of 5 cycles of 1 kHz modulation. Minute pulses of 20 cycles. Voice announcements every 15 m beginning at 0 h 0 m. Time announcement by Morse code beginning at 0 h 5 m. DUT1 : CCIR code by double pulse.
IBF	Torino Italy 45° 2'N 7° 42'E	5 000	During 15 m preceding 7 h, 9 h, 10 h, 11 h, 12 h, 13 h, 14 h, 15h, 16 h, 17 h, 18 h. Advanced by 1 hour in summer.	Second pulses of 5 cycles of 1 kHz modulation. These pulses are repeated 7 times at the minute. Voice announcements at the beginning and end of each emission. Time announcement (C.E.T.) by Morse code every ten minutes beginning at 0 h 0 m. DUT1 : CCIR code by double pulse.
JG2AS	Sanwa Ibaraki Japan 36° 11'N 139° 51'E	40	continuous, except interruptions during communications.	A1 type second pulses of 0.5 s duration. Second 59 is of 0.2 s. No DUT1 code. During experimental coded transmission of the total day, hour, minute and DUT1, second pulses are 0.2 s, 0.5 s and 0.8 s duration.
JJY	Sanwa Ibaraki Japan 36° 11'N 139° 51'E	2 500 5 000 8 000 10 000 15 000	continuous, except interruption between minutes 35 and 39.	Second pulses of 8 cycles of 1 600 Hz modulation. Minute pulses are preceded by a 600 Hz modulation. DUT1 : CCIR code by lengthening.
LOL1	Buenos-Aires Argentina 34° 37'S 58° 21'W	5 000 10 000 15 000	11 h to 12 h, 14 h to 15 h, 17 h to 18 h, 20 h to 21 h, 23 h to 24 h	Second pulses of 5 cycles of 1 000 Hz modulation. Second 59 is omitted. Announcement of hours and minutes every 5 minutes, followed by 3 m of 1 000 Hz or 440 Hz modulation. DUT1 : CCIR code by lengthening.
LOL2 LOL3	Buenos-Aires Argentina 34° 37'S 58° 21'W	4 856 8 030 17 180	1 h, 13 h, 21 h	A1 second pulses during the 5 minutes preceding the indicated times. Second 29 is omitted. Minute pulses are prolonged. DUT1 : CCIR code by double pulse.

Station	Location Latitude Latitude	Frequency (kHz)	Schedule (UTC)	Form of time signals
MSF	Rugby United Kingdom 52° 22'N 1° 11'W	60	continuous except for an interruption for maintenance from 10 h 0 m to 14 h 0 m on the first Tuesday in each month.	Interruptions of the carrier of 100 ms for the second pulses, of 500 ms for the minute pulses. The signal is given by the beginning of the interruption. BCD NRZ code, 100 bits/s (month, day of month, hour, minute), during minute interruption. BCD PWM code, 1 bit/s (year, month, day of month, day of week, hour, minute) from seconds 17 to 59 in each minute. DUT1 : CCIR code by double pulse.
OLB5	Liblice Czechoslovakia 50° 4'N 14° 53'E	3 170	continuous except from 9 h to 14 h on the first Wednesday of every month	A1 type, second pulses. No transmission of DUT1.
OMA (2)	Liblice Czechoslovakia 50° 4'N 14° 53'E	50	continuous (from 6 h to 12 h on the first Wednesday in each month, emitted from Podebrady with reduced power)	Interruption of the carrier of 100 ms at the beginning of every second, of 500 ms at the beginning of every minute. The precise time is given by the beginning of the interruption. Phase coded announcement of date, UT and local civil time. No DUT1 code.
OMA	Liblice Czechoslovakia 50° 4'N 14° 53'E	2 500	continuous except from 9 h to 14 h on the first Wednesday of every month	Pulses of 100 cycles of 1 kHz modulation (prolonged for the minutes) No DUT1 code.
PPE	Rio-de-Janeiro Brasil 22° 54'S 43° 13'W	8 721	0 h 30 m, 11 h 30 m, 13 h 30 m, 19 h 30 m, 20 h 30 m, 23 h 30 m	Second ticks, of A1 type, during the five minutes preceding the indicated times. The minute ticks are longer. DUT1 : CCIR code by double pulse.
PPR	Rio-de-Janeiro Brasil 22° 59'S 43° 11'W	435 4 244 8 634 13 105 17 194.4 22 603	1 h 30 m, 14 h 30 m, 21 h 30 m	Second ticks, of A1 type, during the five minutes preceding the indicated times. The minute ticks are longer.
RBU (3)	Moscow USSR 55° 48'N 38° 18'E	66 2/3	continuous	DXXXW type signals. The time of day in hours, minutes and seconds is transmitted in BCD code. From 9 h to 11 h, 19 h to 23 h, NON type signals.
RCH (3)	Tashkent USSR 41° 19'N 69° 15'E	 2 500 5 000 10 000	Winter schedule : between minutes 0 and 10, 30 and 40 0 h to 3 h 40 m 5 h to 23 h 40 m 0 h to 3 h 40 m 14 h to 23 h 40 m 5 h to 13 h 10 m In summer add one hour.	A1X type second pulses. The pulses at the beginning of the minute are prolonged to 0.5 s.
RID (3)	Irkutsk USSR 52° 26'N 104° 2'E	5 004 10 004 15 004	The station simultaneously operates on three frequencies between minutes 20 and 30, 50 and 60	A1X type second pulses. The pulses at the beginning of the minute are prolonged to 0.5 s.

Notes : see p. C-10

Station	Location Latitude Longitude	Frequency (kHz)	Schedule (UTC)	Form of time signals
RTA (3)	Novosibirsk USSR 55° 4'N 82° 58'E	10 000 15 000	Winter schedule : between minutes 0 and 10, 30 and 40, 14 h to 5 h 10 m 6 h 30 m to 13 h 10 m In summer add one hour.	A1X type second pulses. The pulses at the beginning of the minute are prolonged to 0.5 s.
RWM (3)	Moscow USSR 55° 48'N 38° 18'E	4 996 9 996 14 996	The station simultaneously operates on three frequencies between minutes 10 and 20, 40 and 50	A1X type second pulses. The pulses at the beginning of the minute are prolonged to 0.5 s.
RTZ (3)	Irkutsk USSR 52° 26'N 104° 2'E	50	between minutes 0 and 5 0 h to 20 h 05 m 22 h to 23 h 05 m	A1X type second pulses. The pulses at the beginning of the minute are prolonged to 0.5 s.
TDF	Allouis France 47° 10'N 2° 12'E	162	continuous except every Tuesday from 1 h to 5 h	Phase modulation of the carrier by + and - 1 radian in 0.1 s every second except the 59th second of each minute. This modulation is doubled to indicate binary 1. The numbers of the minute, hour, day of the month, day of the week, month and year are transmitted each minute from the 21st to the 58th second, in accordance with the French legal time scale. In addition a binary 1 at the 17th second indicates that the local time is 2 hours ahead of UTC(summer time), a binary 1 at the 18th second indicates when the local time is one hour ahead of UTC(winter time) ; a binary 1 at the 14th second indicates that the current day is a public holiday (Christmas, 14 July, etc...); a binary 1 at the 13th second indicates that the current day is a day before a public holiday.
UNW3	Molodechno USSR 54° 26'N 26° 48'E	25	7 h 13 m to 7 h 22 m 13 h 13 m to 13 h 22 m in winter 6 h 13 m to 6 h 22 m 12 h 13 m to 12 h 22 m in summer	A1N type 0.1 second pulses of 0.025 s duration. Second pulses are prolonged to 0.1 s. 10 second pulses are prolonged to 1 s and minute pulses are prolonged to 10 s. No transmission of DUT1 code.
UPD8	Arkhangelsk USSR 64° 24'N 41° 32'E	25	11 h 13 m to 11 h 22 m 21 h 13 m to 21 h 22 m in winter 2 h 13 m to 2 h 22 m 8 h 13 m to 8 h 22 m in summer	A1N type 0.1 second pulses of 0.025 s duration. Second pulses are prolonged to 0.1 s. 10 second pulses are prolonged to 1 s and minute pulses are prolonged to 10 s. No transmission of DUT1 code.
UQC3	Chabarovsk USSR 48° 30'N 134° 51'E	25	2 h 13 m to 2 h 22 m 8 h 13 m to 8 h 22 m 14 h 13 m to 14 h 22 m in winter 1 h 13 m to 1 h 22 m 7 h 13 m to 7 h 22 m 13 h 13 m to 13 h 22 m in summer	A1N type 0.1 second pulses of 0.025 s duration. Second pulses are prolonged to 0.1 s. 10 second pulses are prolonged to 1 s and minute pulses are prolonged to 10 s. No transmission of DUT1 code.

Notes : see p. C-10

Station	Location Latitude Longitude	Frequency (kHz)	Schedule (UTC)	Form of time signals
USB2	Frunze USSR 43° 04'N 73° 39'E	25	4 h 13 m to 4 h 22 m 10 h 13 m to 10 h 22 m 16 h 13 m to 16 h 22 m in winter 3 h 13 m to 3 h 22 m 9 h 13 m to 9 h 22 m 19 h 13 m to 19 h 22 m in summer	A1N type 0.1 second pulses of 0.025 s duration. Second pulses are prolonged to 0.1 s. 10 second pulses are prolonged to 1 s and minute pulses are prolonged to 10 s. No transmission of DUT1 code.
UTR3	Gorki USSR 56° 11'N 43° 58'E	25	5 h 13 m to 5 h 22 m 19 h 13 m to 19 h 22 m in winter 4 h 13 m to 4 h 22 m 18 h 13 m to 18 h 22 m in summer	A1N type 0.1 second pulses of 0.025 s duration. Second pulses are prolonged to 0.1 s 10 second pulses are prolonged to 1 s and minute pulses are prolonged to 10 s. No transmission of DUT1 code.
WWV	Fort-Collins, CO USA 40° 41'N 105° 2'W	2 500 5 000 10 000 15 000 20 000	continuous	Pulses of 5 cycles of 1 kHz modulation. 59th and 29th second pulses omitted. Hour is identified by 0.8 second long 1 500 Hz tone. beginning of each minute identified by 0.8 second long 1 000 Hz tone. DUT1 : CCIR code by double pulse. BCD time code given on 100 Hz subcarrier, includes DUT1 correction.
WWVB	Fort-Collins, CO USA 40° 40'N 105° 3'W	60	continuous	Second pulses given by reduction of the amplitude of the carrier. Coded announcement of the date, time, correction to obtain UT1, daylight savings time in effect and leap year. No CCIR code.
WWVH	Kauai, HI USA 21° 59'N 159° 46'W	2 500 5 000 10 000 15 000	continuous	Pulses of 6 cycles of 1 200 Hz modulation. 59th and 29th second pulses omitted. Hour identified by 0.8 second long 1 500 Hz tone. Beginning of each minute identified by 0.8 second long 1 200 Hz tone. DUT1 : CCIR code by double pulse. BCD time code given on 100 Hz subcarrier, includes DUT1 correction.
YVTO	Caracas Venezuela 10° 30'N 66° 56'W	5 000	continuous	Second pulses of 1 kHz modulation with 0.1 s duration. The minute is identified by a 800 Hz tone and a 0.5 s duration. Second 30 is omitted. Between seconds 40 and 50 of each minute, voice announcement of the identification of the station. Between seconds 52 and 57 of each minute, voice announcement of hour, minute and second.
Y3S (4)	Nauen Germ. Dem. Rep. 52° 39'N 12° 55'E	4 525	continuous except from 8 h 15 m to 9 h 45 m for maintenance if necessary	A1 type second pulses of 0.1 s duration. Minute pulses prolonged to 0.5 s. DUT1 : CCIR code by double pulse.

Notes : see p. C-10

NOTES ON THE CHARACTERISTICS OF THE SIGNALS

(1) No recent information on these time signals.

(2) OMA, 50 kHz

a. The main transmitter in Liblice radiates approx. 7 kW and the stand-by transmitter in Podebrady (50° 9'N, 15° 9'E) approx. 50 W.

b. The details of the time code were published in Nomenclature des stations de radiorepérage et des stations effectuant des services spéciaux - Liste VI, Volume I, édition 7 de U.I.T. in Geneva in July 1980.

(3) The radiostations of the USSR emit DUT1 information in accordance with the CCIR code. Furthermore they give an additional information dUT1 specifying more precisely the difference UT1 - UTC down to multiples of 0.02 s, the total value of the correction being DUT1 + dUT1. Positive values of dUT1 are transmitted by the marking of p second markers within the range between the 21th an 24th second so that dUT1 = + 0.02 s x p. Negative values of dUT1 are transmitted by the marking of q second markers within the range between the 31th and the 34th second, so that dUT1 = -0.02 s x q.

(4) DUT1 information in CCIR code.
dUT1 information. This additional information specifies more precisely the difference UT1 - UTC down to multiples of 0.02 s, the total value of the correction being DUT1 + dUT1.

A positive value of dUT1 is indicated by doubling a number (p) of consecutive seconds markers from second marker 21 to second marker (20 + p) inclusive ; (p) being an integer from 1 to 5 inclusive.

$$dUT1 = p.0.02 \text{ s.}$$

A negative value of dUT1 is indicated by doubling a number (q) of consecutive seconds markers following the minute marker from second marker 31 to second marker (30 + q) inclusive ; (q) being an integer from 1 to 5 inclusive.

$$dUT1 = -(q.0.02) \text{ s.}$$

The second marker 28 following the minute marker is doubled as parity bit, if the value of (p) or (q) is an even number or if dUT1 = 0.

Time-information. During the last 20 seconds of each minute in a BCD-Code an information about the value "minute" and "hour" in the UTC time scale of the following minute marker is given.

UNCERTAINTY OF THE CARRIER FREQUENCY

The carriers of the following time signals are standard frequencies.

Station	Relative uncertainty of the carrier frequency in 10^{-10}
ATA	0.1
BPM	0.1
BSF	0.2
CHU	0.05
DCF77	0.005 (10d-mean)
EBC	0.1
HBG	0.005
HLA	0.1
IAM	0.5
IBF	0.1
JJY, JG2AS	0.1
LOL1	0.1
MSF	0.02
OMA (all frequencies)	0.5
RBU, RTZ	0.05
RCH, RID, RTA, RWM	0.5
TDF	0.02
UNW3, UPD8, UQC3, USB2, UTR3	0.05
WWV	0.1
WWVB	0.1
WWVH	0.1

TIME OF EMISSION OF THE TIME SIGNALS IN THE UTC SYSTEM, IN 1989

The following deviations of the time of emission of the time signals, from UTC, have been reported to the BIPM, or observed.

ATA	UTC-ATA = -0.0500 s
BPM	UTC-BPM = -0.0200 s
OLB5	UTC-OLB5= 0.0008 s

PART D

SCIENTIFIC CONTRIBUTIONS

PARTIE D

CONTRIBUTIONS SCIENTIFIQUES

A Study of Data From Two GPS Ionospheric Calibrators

Marc A. Weiss*
Time and Frequency Division
National Institute of Standards and Technology
325 Broadway
Boulder, CO 80303
U.S.A.

Claudine Thomas
Time Section
Bureau International des Poids et Mesures
Pavillon de Breteuil
92312 Sèvres Cedex
France

* guest-worker at the BIPM from March to May 1990

Introduction

Two new devices use signals from Global Positioning System (GPS) satellites to measure the thickness of the ionosphere by measuring the delay of the signals as they pass through the ionosphere. The first was built at the Bureau International des Poids et Mesures by M. Imae, a guest worker from the Communications Research Laboratory (CRL) in Tokyo, Japan. The second was built at the National Institute of Standards and Technology (NIST), Boulder, Colorado, USA, by D. Davis, M. Weiss and M. Vidmar. M. Vidmar was a guest worker from the University of Ljubljana, Yugoslavia. Both systems are designed to correct GPS time measurements using a measured ionospheric delay and both use a dual frequency codeless technique. Receivers of the NIST type make measurements every 15 seconds and make 15-minute linear fits to them. Those of the CRL type store data every 4 minutes. Both systems are described more fully elsewhere [1, 2]. One system of the CRL type has been in use at the BIPM in Sèvres near Paris, since September 1988, while one of the NIST calibrators has been in use at the Observatoire de Paris (OP) in Paris since November 1989. The distance between these laboratories is of the order of 10 km. We present here an analysis of data taken from the two receivers over a period of 19 days in March 1990. We show: 1) the vertical delay through the ionosphere as measured by the two calibrators, 2) the ionospheric delay from a given satellite over individual passes, 3) plots of the difference of measurements between the two calibrators, and 4) a variance analysis of the stability of the two systems.

I. Vertical ionospheric delay

Both receivers measure the ionospheric delay of the GPS signal along the line of sight of a satellite. To compare the results obtained from different satellites observed for different positions in the sky, it is useful to convert the measured values into vertical estimates. For this conversion, a simple geometric expression is used where the ionosphere is modelled as a spherical shell of uniform electron density extending from 200 km to 450 km in height. A correction is applied for the non-flatness of the earth and for the azimuth of the observed satellite.

Figures 1a, 1b, 2a, and 2b present the vertical delays measured at the OP and at the BIPM from MJD 47971 (1990 March 21) to MJD 47986 (1990 April 5). These plots are obtained from a number of selected tracks: when a value is obtained at the BIPM at a given time, a value is estimated at OP by linear interpolation using two neighbouring 15-minute tracks of the same satellite surrounding the BIPM time of observation. Only the points corresponding to the superposition are reported on Figs. 1 and 2. The NIST calibrator at OP provides much more data than is plotted here.

On Figs. 1 and 2, the usual diurnal variation of the vertical ionospheric delay can be observed and there is good agreement between the two calibrators. The delay shows structures that are attributed to sudden changes in the ionosphere which could not be predicted by the usual ionospheric model broadcast in the GPS message. In interpreting this, however, one must keep in mind that the satellites are in different parts of the sky, so sudden differences in the vertical delay are not unexpected.

II. Ionospheric delay from a given satellite over individual passes

Figure 3a shows the elevation plot for PRN 17 and Fig. 3b, the ionospheric delay measured at the BIPM along the line of sight of PRN 17, for 11 consecutive days starting on MJD 47971 (1990 March 21). The time of the day is adjusted for the 4 minute shift of solar time required by the sidereal repeatibility of the GPS system. Since these tracks span sunset and continue into the night, the measured delay decreases continuously.

The plot of Fig. 3b gives a clear indication of the presence of multipath interference: common daily patterns with amplitudes of up to 5 ns cannot be attributed to sudden changes in the ionosphere, but correspond to given directions of observation. These patterns have a period of approximately 15 minutes, an effect seen previously in multipath interference of this type [3].

We note that the directional antenna used by the CRL type ionospheric calibrator does not completely eliminate multipath interference in the reception of GPS signals. A similar result was found at NIST in the development of their GPS C/A code time transfer receiver, though in that case the system tracked the C/A code, while here both systems use a "codeless" technique with the P-code.

Comparable plots are shown on Figs. 4a and 4b for PRN 3. Here we see measured ionospheric delays from the NIST ionospheric calibrator at the OP averaged over 1 minute. Multipath effects can be observed, but with smaller amplitudes. Recall that the NIST calibrator operates with an omnidirectional antenna. While we were unable in this study to isolate large multipath effects in the data from the receiver at OP, similar systems in use in Boulder have exhibited multipath effects, sometimes with a peak-to-peak amplitude of 10 ns.

Measured ionospheric delays obtained from PRN 3 over individual passes at OP are reported on Fig. 5 for a 15 minute averaging time. The multipath effects here are almost completely smoothed out.

III. Differences between the measurements from the two calibrators

The differences of the measured ionospheric delays obtained from the two calibrators located at OP and at the BIPM have been computed for the block I satellites (PRN 3, 6, 9, 11, 12 and 13) for 15 consecutive days.

The BIPM values correspond to 4-minute averages and the OP values to 15-minute averages. As described in part I, a value is estimated for the OP calibrator by linear interpolation from two neighbouring 15-minute tracks surrounding the BIPM time of observation.

The mean differences and the corresponding standard deviations are:

PRN	d(ns)	σ(ns)
3	1.9	2.6
6	2.6	2.7
9	5.6	2.3
11	1.6	2.3
12	3.6	2.0
13	3.1	2.8

There appears to be a bias between the two calibrators, the values measured at OP being larger on average by a few ns, than the BIPM ones.

The difference of the OP and the BIPM ionospheric delays are reported on Fig. 6 for PRN 6 (8 individual passes) and on Fig. 7 for PRN 9 (11 individual passes). These plots again give clear evidence of multipath effects between the two systems. Hence, these differences do not exhibit white noise, and the above standard deviations are affected by this.

IV. Stability of the two systems

Figure 8 represents the raw data taken at OP every 15 seconds from PRN 3 during a single pass on MJD 47972 (1990 March 22). The modified Allan variance computed from these data is plotted on Fig. 9. The NIST calibrator measurements are consistent with a model of white phase noise modulation (PM) for integration times of less than 500 s. The definitive results, obtained with the NIST calibrator over an averaging time of 900 seconds, then show the physical effects after a filtering of white PM.

For white phase noise, the stability can be expressed by the classical variance σ_x^2. This is then related to the Allan variance of frequency $\sigma_y^2(\tau)$ by:

$$\sigma_x = \frac{\tau . \sigma_y(\tau)}{\sqrt{3}} \qquad (1)$$

Since the data are compatible with white phase noise, we thus estimate the time stability of the 15 second data of the NIST ionospheric calibrator to be about 2 ns.

Figure 10 shows the modified Allan variance for the BIPM data obtained as 4-minute averages. The bump observed from about 800 to 900 seconds can be interpreted as due to multipath effects. The BIPM data also exhibit white phase noise, for $\tau < 1500$ s. According to Eq. (1), the time stability of the 4 minute data for the CRL type ionospheric calibrator is about 1 ns.

V. Conclusions

This comparative study of the data from the two ionospheric calibrators (NIST and CRL types) located at the OP and at the BIPM shows a good global agreement of the vertical values. Detailed analysis of the ionospheric delays obtained along the lines of sight of the satellites points out a bias of a few ns. The deviation around this bias is perturbed by multipath effects which affect both calibrators, even though a directive antenna is used for the CRL receiver. The stability of the measurements is about 2 ns at 15 seconds of integration time for the NIST calibrator and about 1 ns at 4 minutes of integration time for the CRL type calibrator. The ionospheric measurements are averaged over 15 minutes so that they may be applied directly to the GPS common view time comparisons. For averaging times of this length the white phase noise present in the raw data is smoothed out.

Acknowledgements

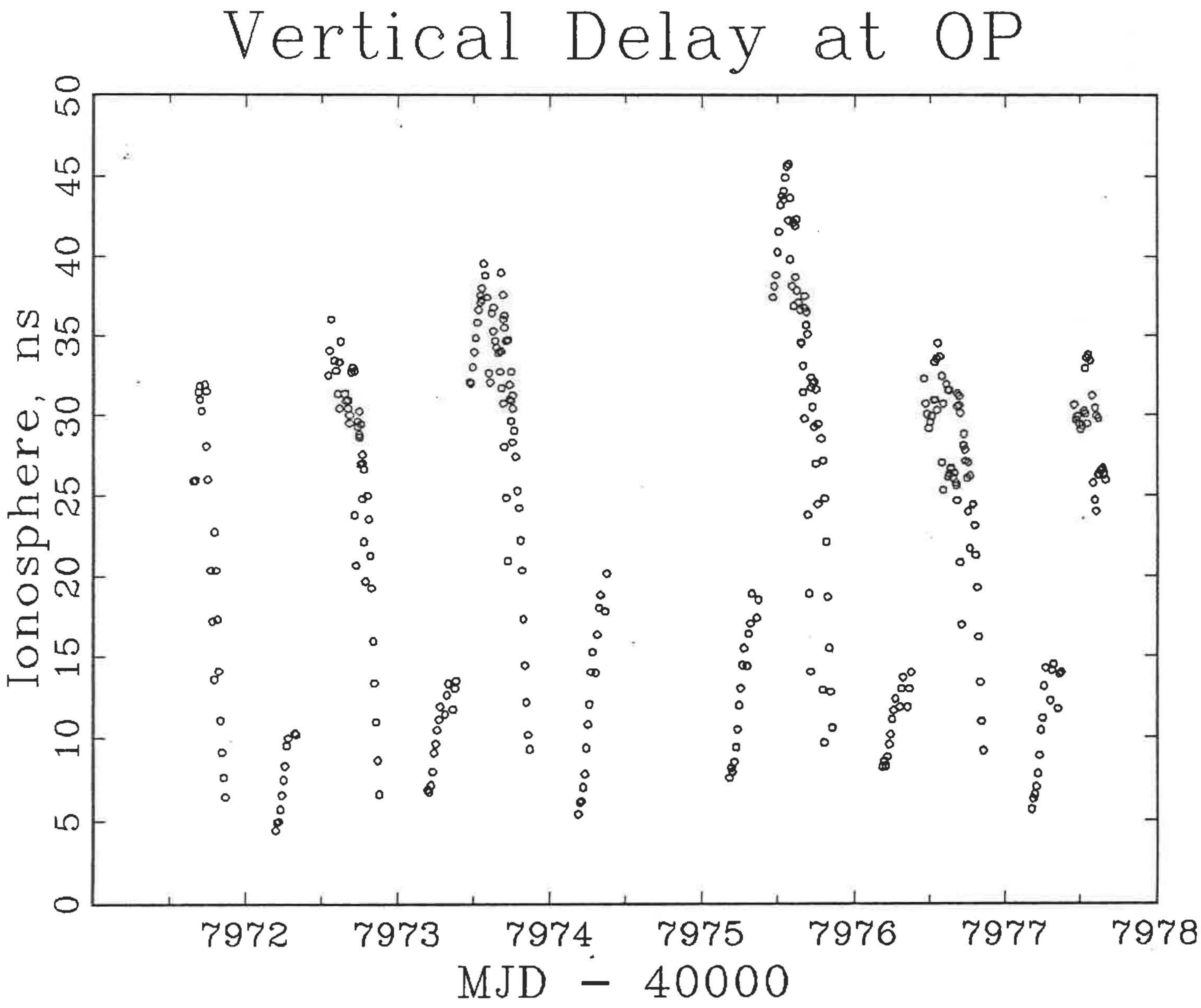
The authors are grateful to P. Uhrich for his assistance in collecting the data at the OP.

References

[1] Imae M., Lewandowski W., Thomas C. and Niki C., "A dual frequency GPS receiver measuring ionospheric effects without code demodulation and its application to time comparisons", Proceedings of the 20th Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting, 1988, pp. 77-86.

[2] Davis D., Weiss M. and Vidmar M., "A codeless ionospheric calibrator for time transfer applications", Proceedings of the Institute of Navigation Satellite Division, 2nd International Technical Meeting (ION GPS-89), 1989.

[3] Klobuchar J., Air Force Geophysics Laboratory, Hanscom Air Force Base, MA 01731, USA, private communication.


Vertical Delay at OP
Ionosphere, ns
0
5
10
15
20
25
30
35
40
45
50
7972
7973
7974
7975
7976
7977
7978
MJD - 40000
Fig. 1a

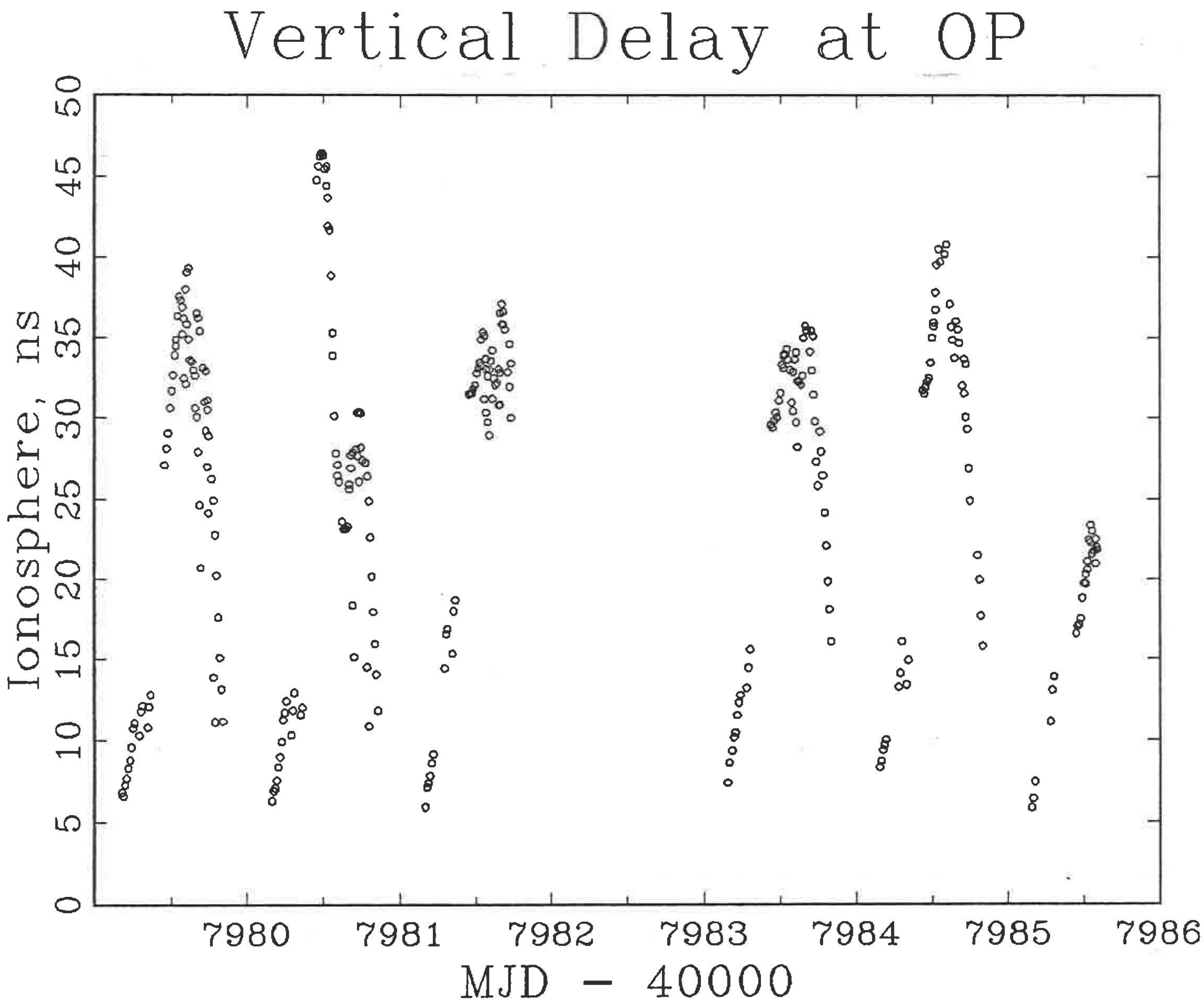

Vertical Delay at OP
Ionosphere, ns
0
5
10
15
20
25
30
35
40
45
50
7980
7981
7982
7983
7984
7985
7986
MJD − 40000

Fig. 1b

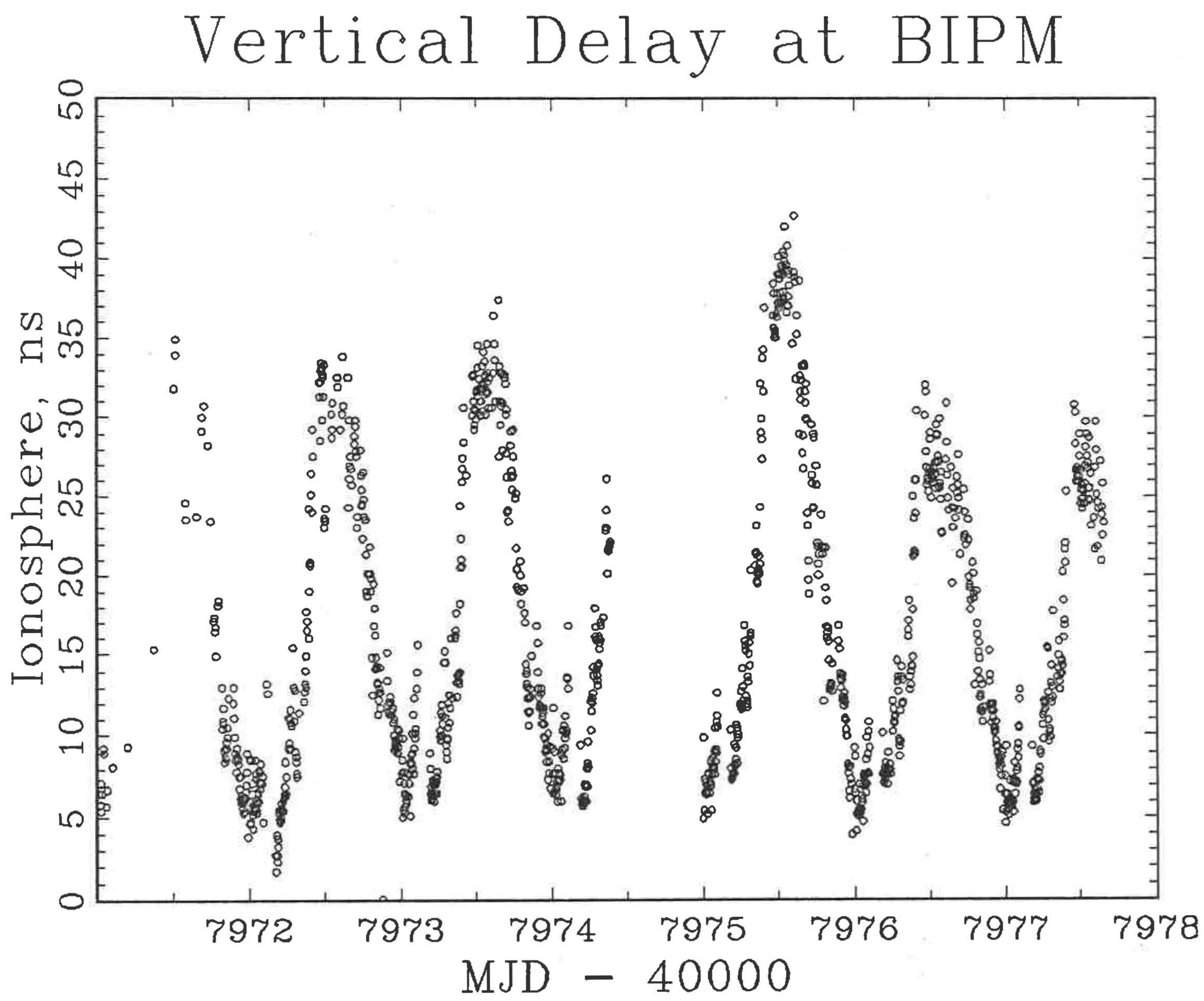

Vertical Delay at BIPM
Ionosphere, ns
0
5
10
15
20
25
30
35
40
45
50
7972
7973
7974
7975
7976
7977
7978
MJD - 40000

Fig. 2a

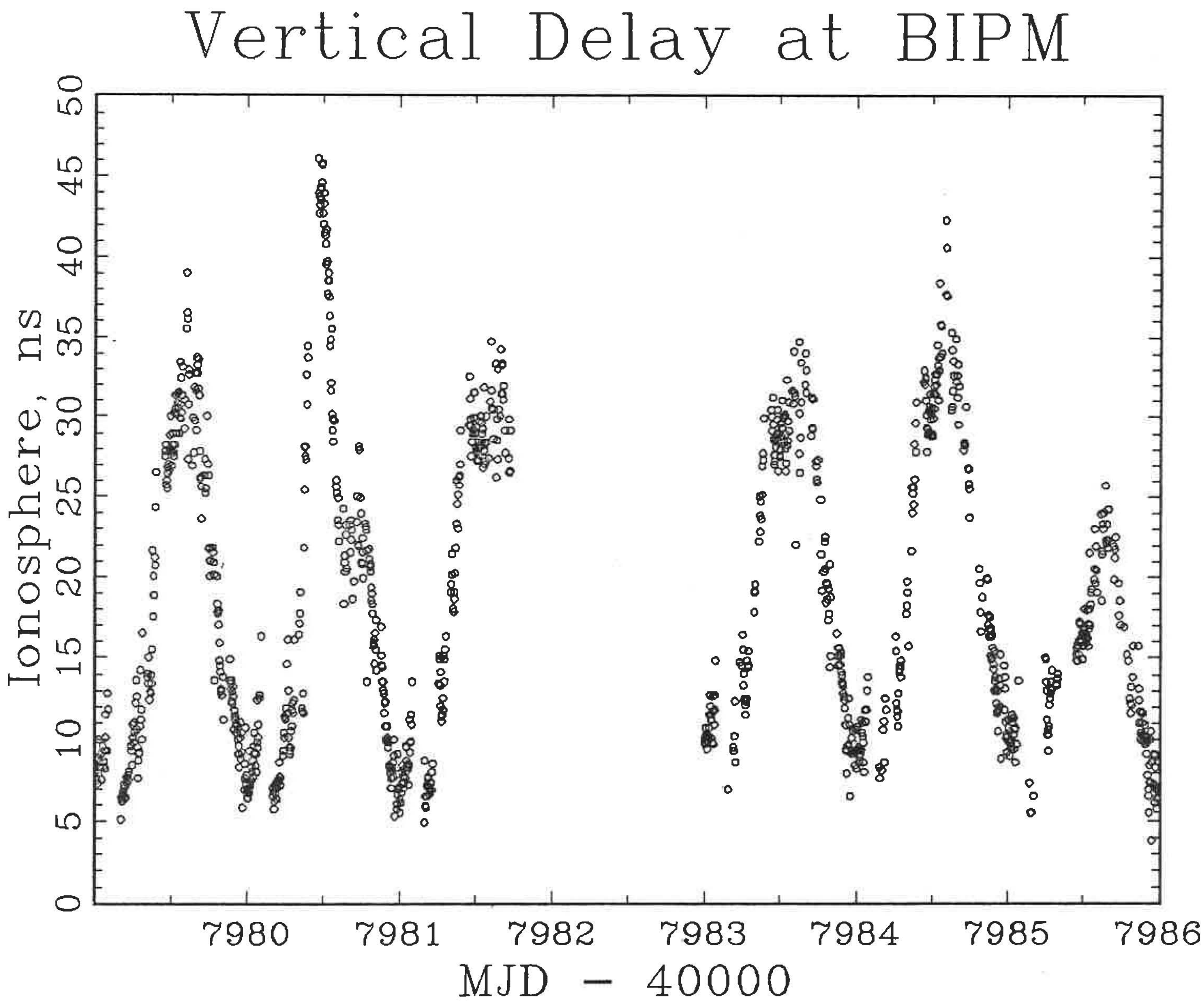

Vertical Delay at BIPM
Ionosphere, ns
0
5
10
15
20
25
30
35
40
45
50
7980
7981
7982
7983
7984
7985
7986
MJD - 40000

Fig. 2b

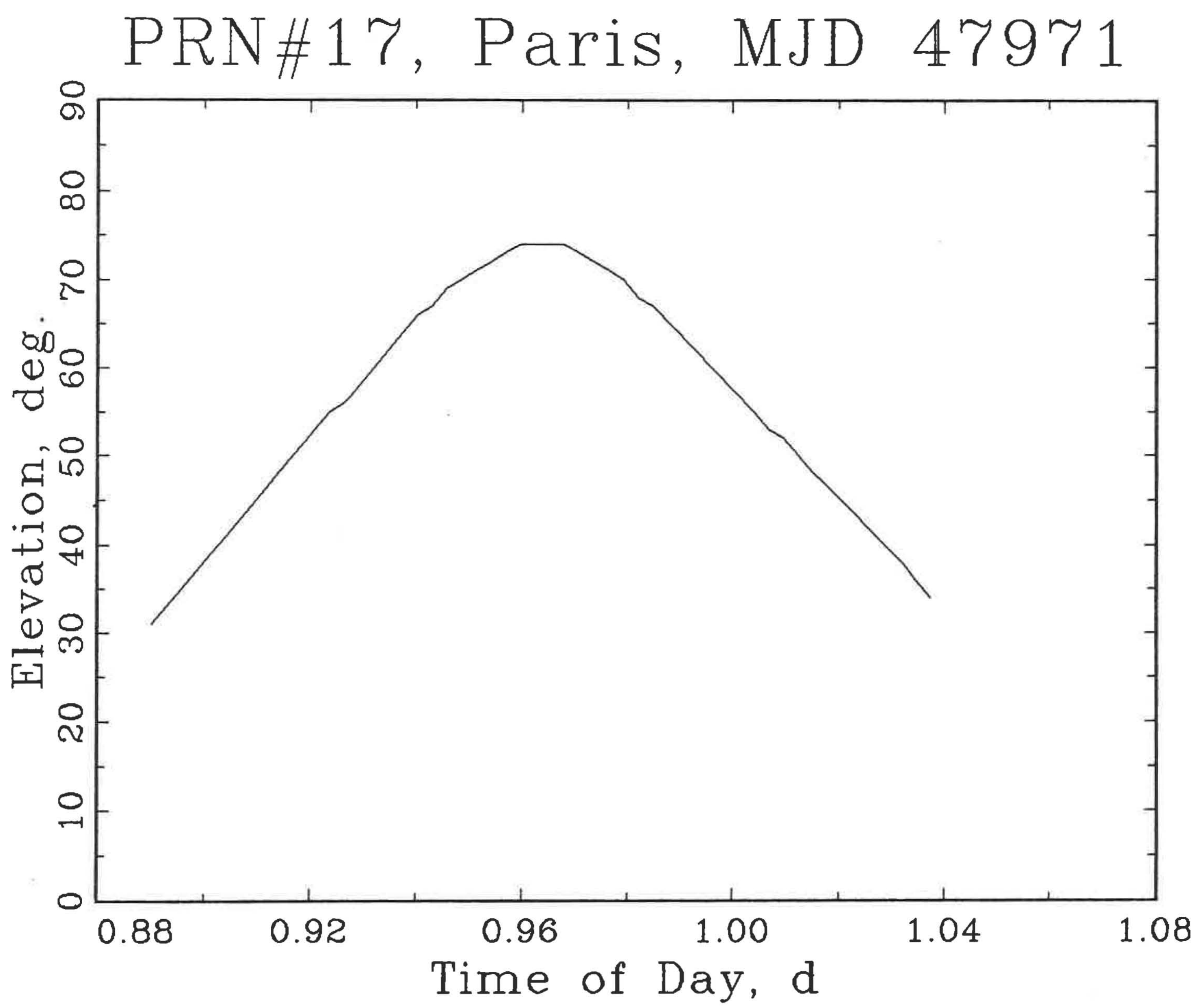

PRN#17, Paris, MJD 47971
Elevation, deg.
0
10
20
30
40
50
60
70
80
90
0.88
0.92
0.96
1.00
1.04
1.08
Time of Day, d

Fig. 3a

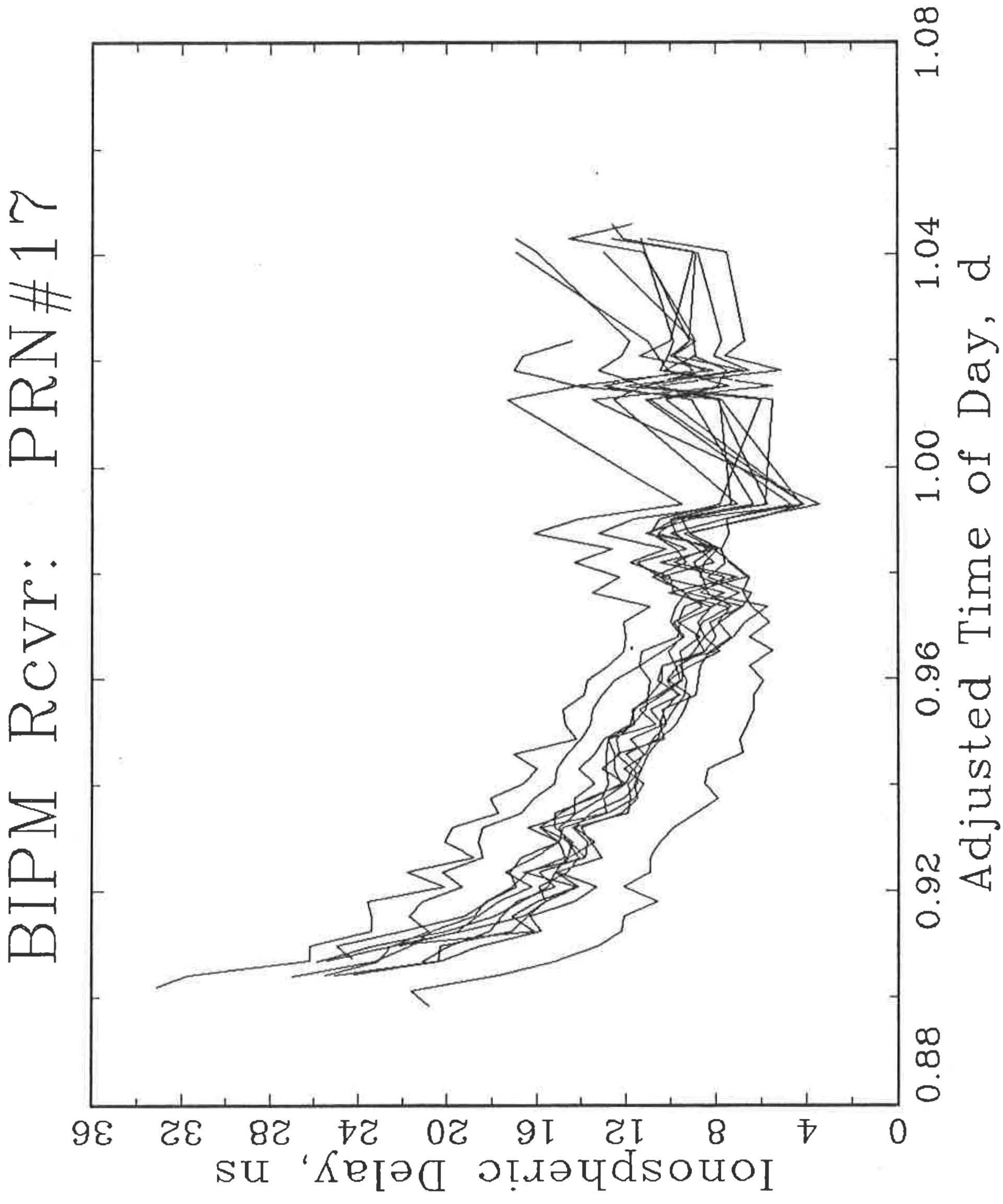

BIPM Rcvr: PRN#17
Ionospheric Delay, ns
Adjusted Time of Day, d
0
4
8
12
16
20
24
28
32
36
0.88
0.92
0.96
1.00
1.04
1.08

Fig. 3b

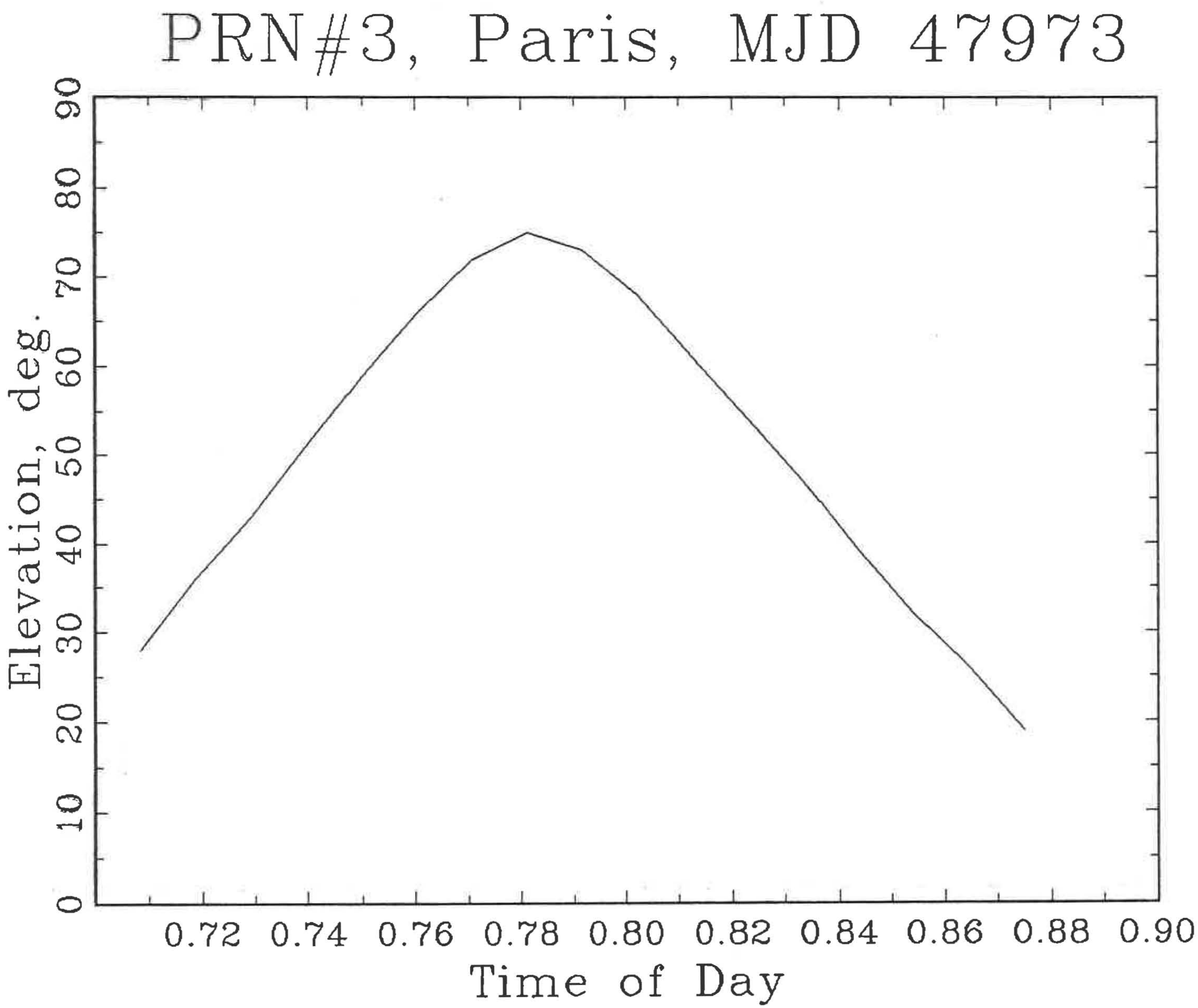

PRN#3, Paris, MJD 47973
Elevation, deg.
0
10
20
30
40
50
60
70
80
90
0.72
0.74
0.76
0.78
0.80
0.82
0.84
0.86
0.88
0.90
Time of Day

Fig. 4a

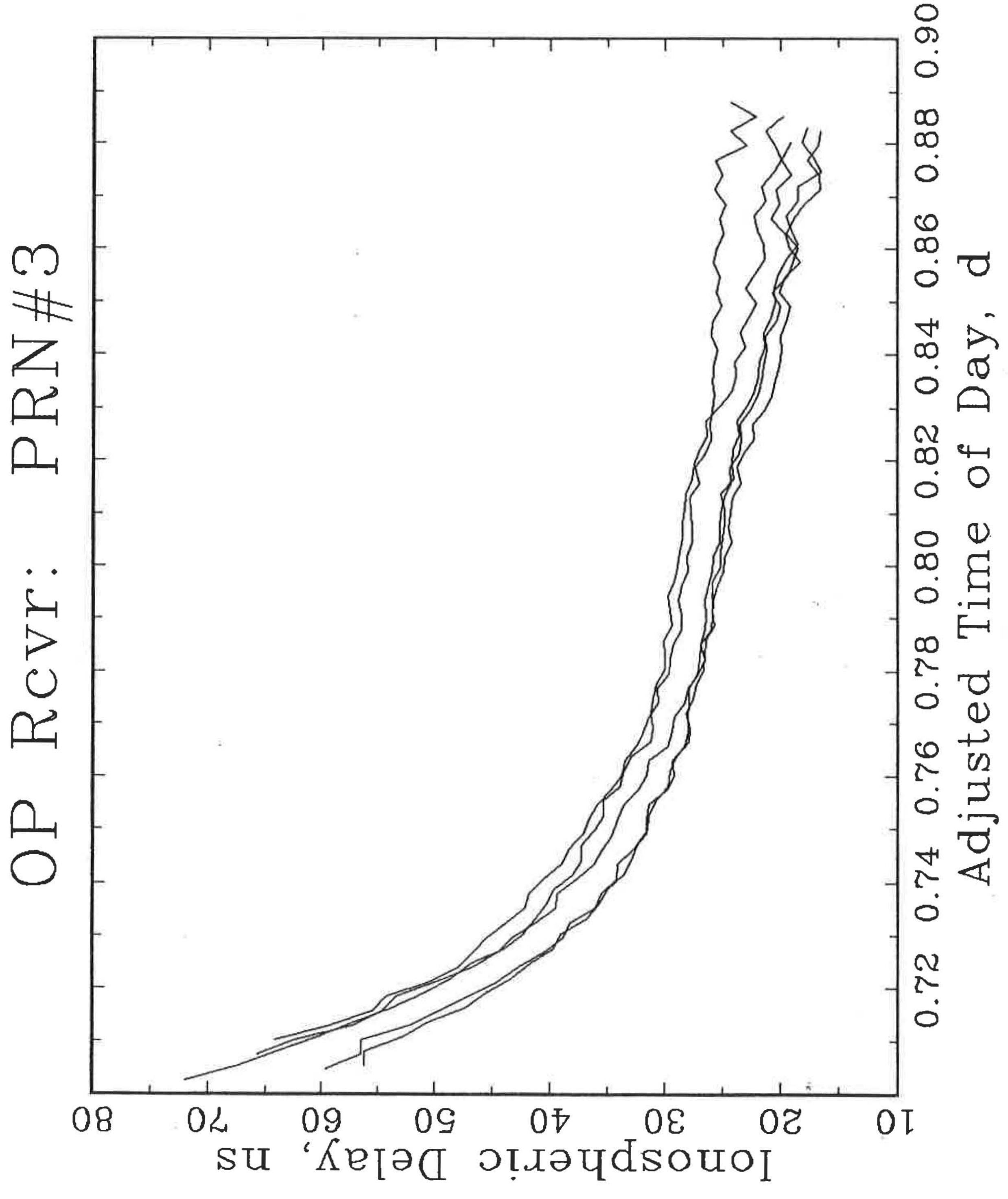
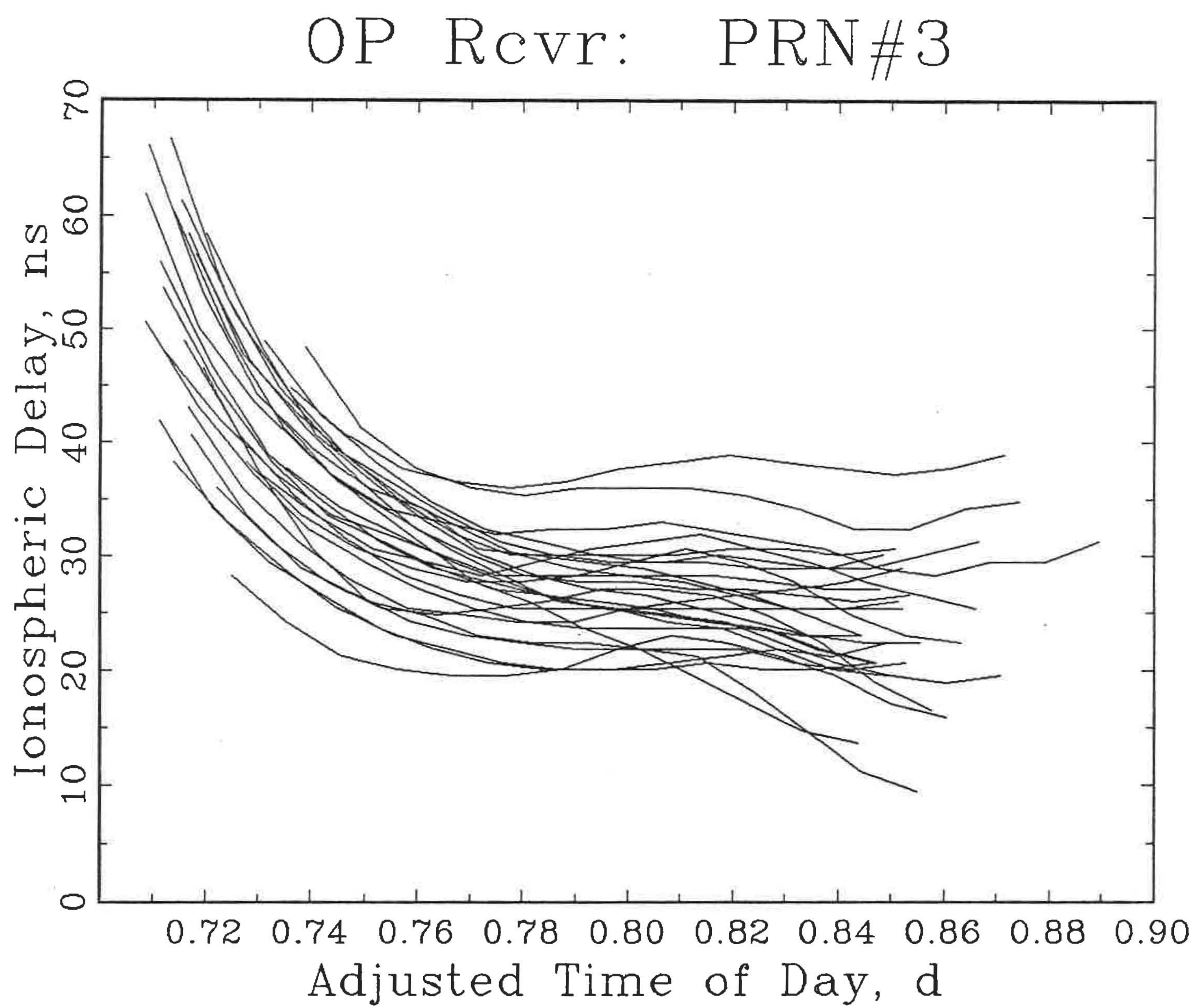

OP Rcvr: PRN#3
Adjusted Time of Day, d
0.72 0.74 0.76 0.78 0.80 0.82 0.84 0.86 0.88 0.90
Ionospheric Delay, ns
10 20 30 40 50 60 70 80

Fig. 4b



OP Rcvr: PRN#3
Ionospheric Delay, ns
0
10
20
30
40
50
60
70
0.72
0.74
0.76
0.78
0.80
0.82
0.84
0.86
0.88
0.90
Adjusted Time of Day, d

Fig. 5

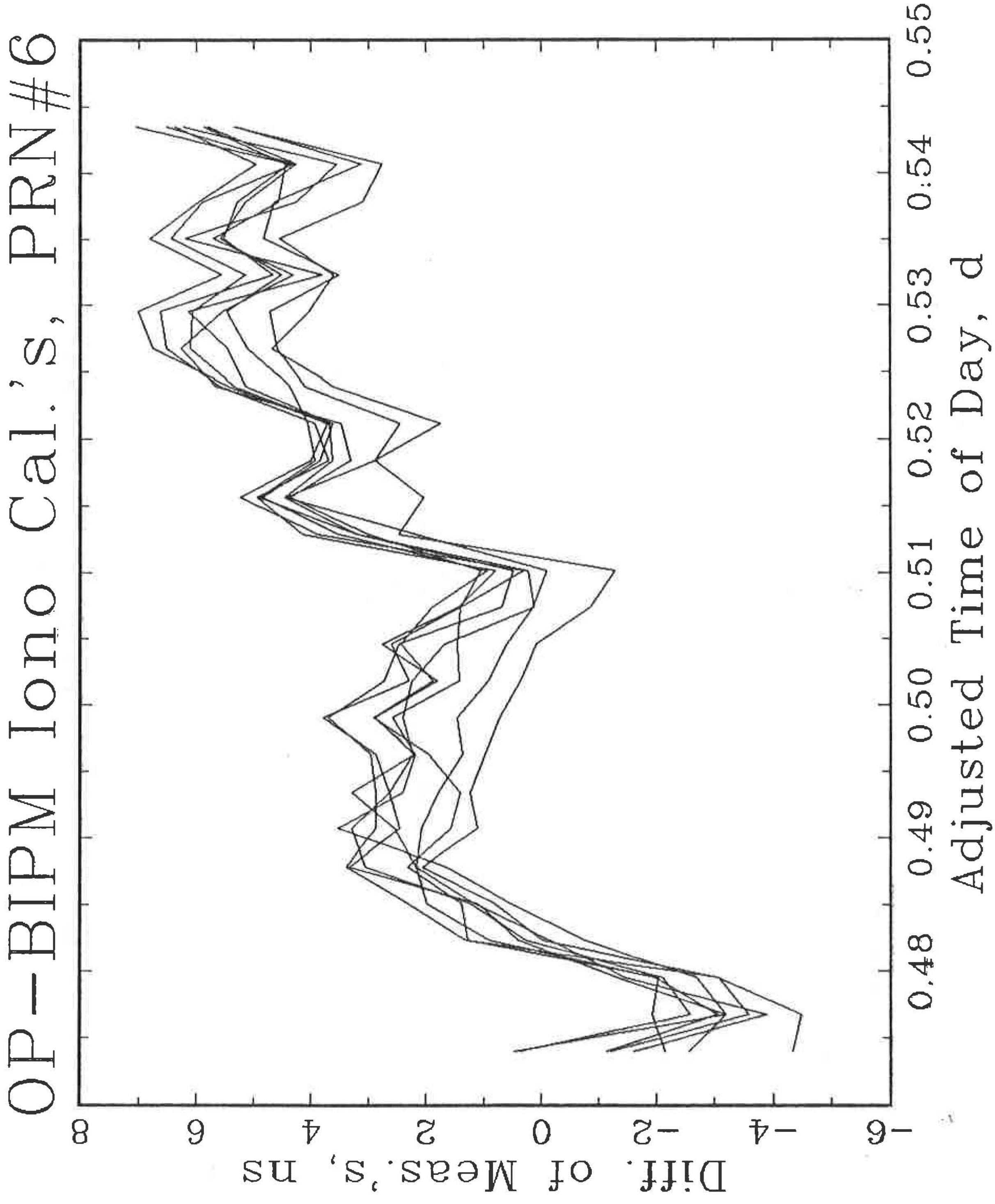
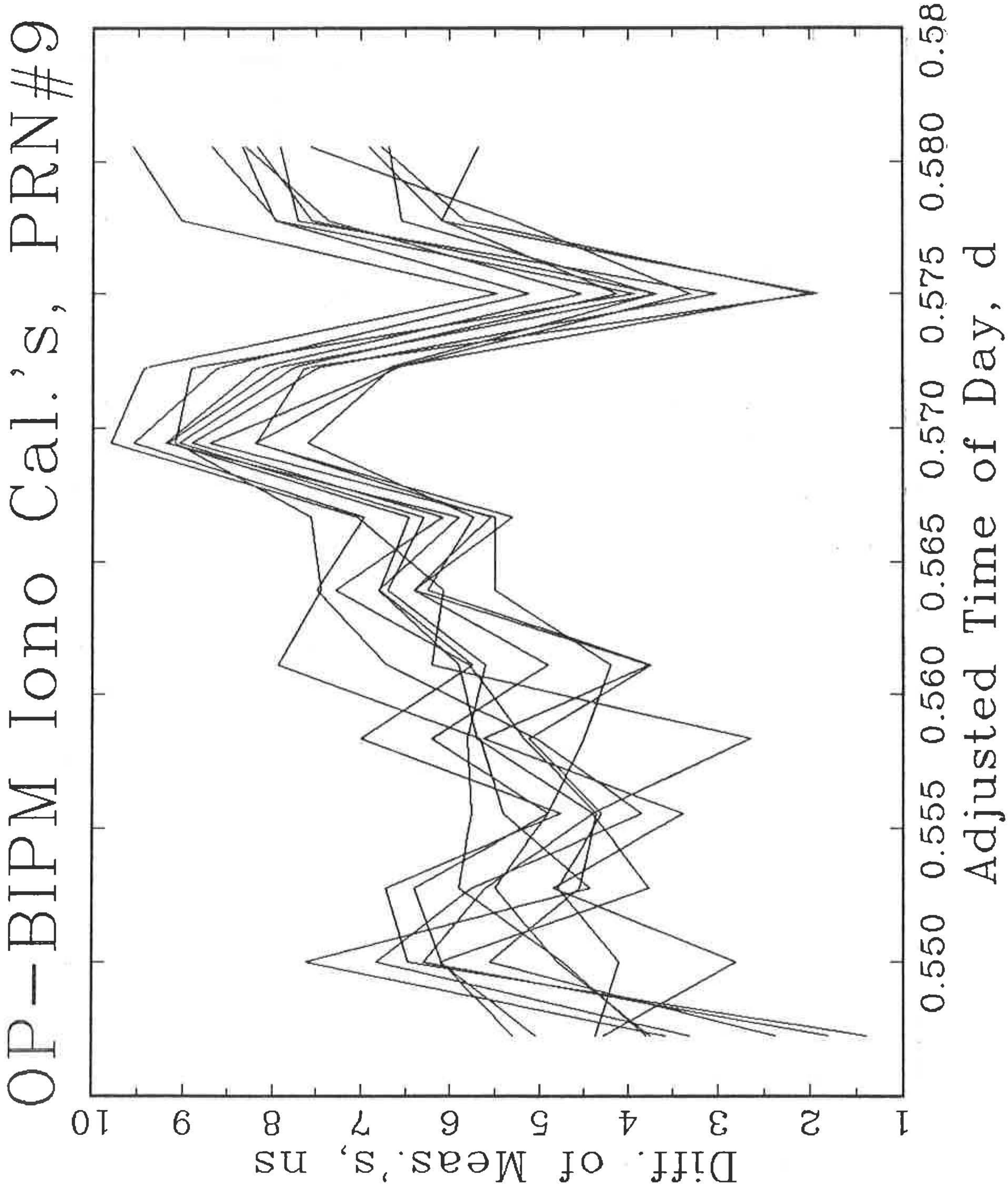

OP-BIPM Iono Cal.'s, PRN#6
Adjusted Time of Day, d
0.48
0.49
0.50
0.51
0.52
0.53
0.54
0.55
Diff. of Meas.'s, ns
8
6
4
2
0
-2
-4
-6

Fig. 6



OP-BIPM Iono Cal.'s, PRN#9
Adjusted Time of Day, d
Diff. of Meas.'s, ns
0.550
0.555
0.560
0.565
0.570
0.575
0.580
0.585
1
2
3
4
5
6
7
8
9
10

Fig. 7

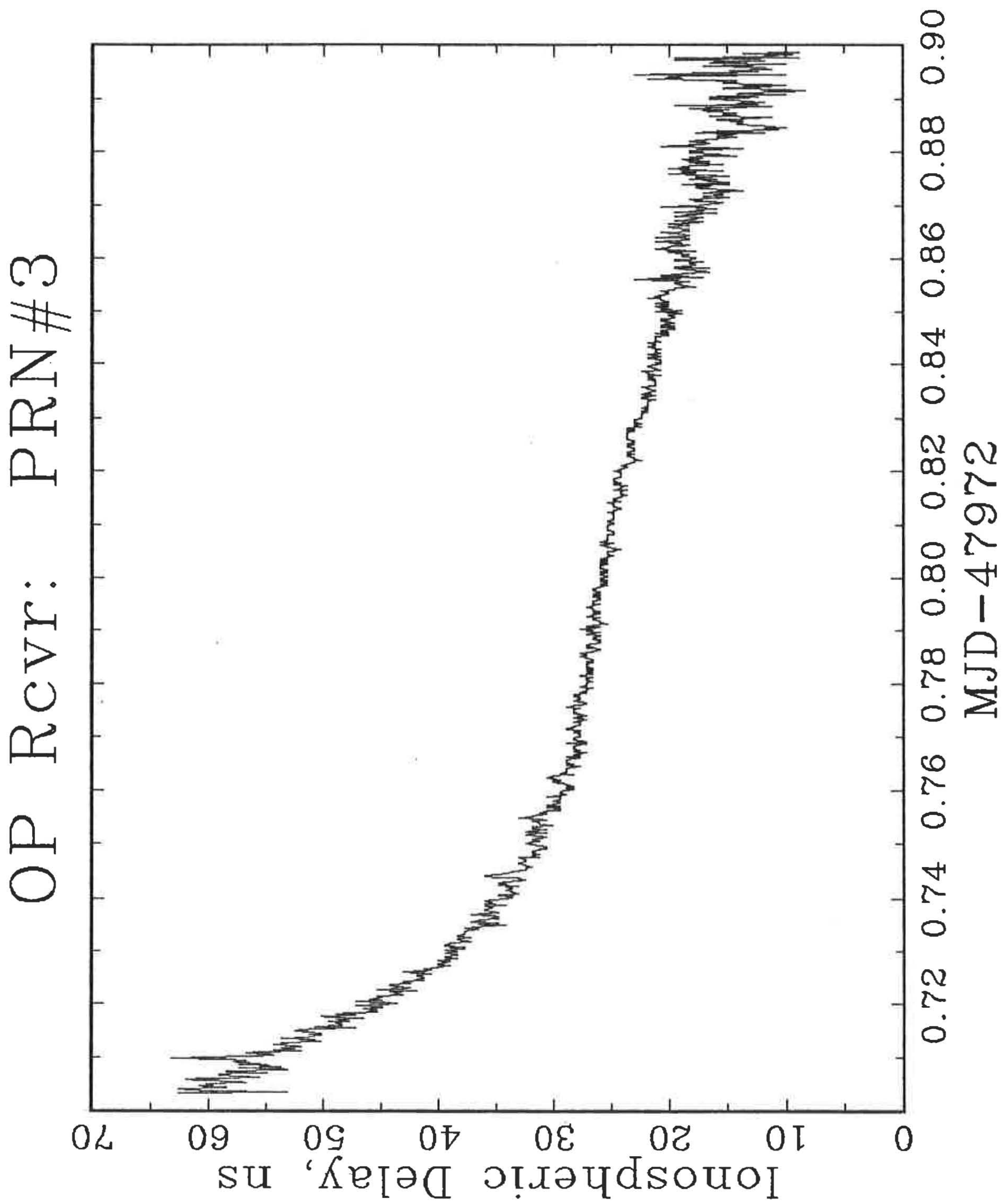

OP Rcvr: PRN#3
Ionospheric Delay, ns
0
10
20
30
40
50
60
70
MJD-47972
0.72
0.74
0.76
0.78
0.80
0.82
0.84
0.86
0.88
0.90

Fig. 8

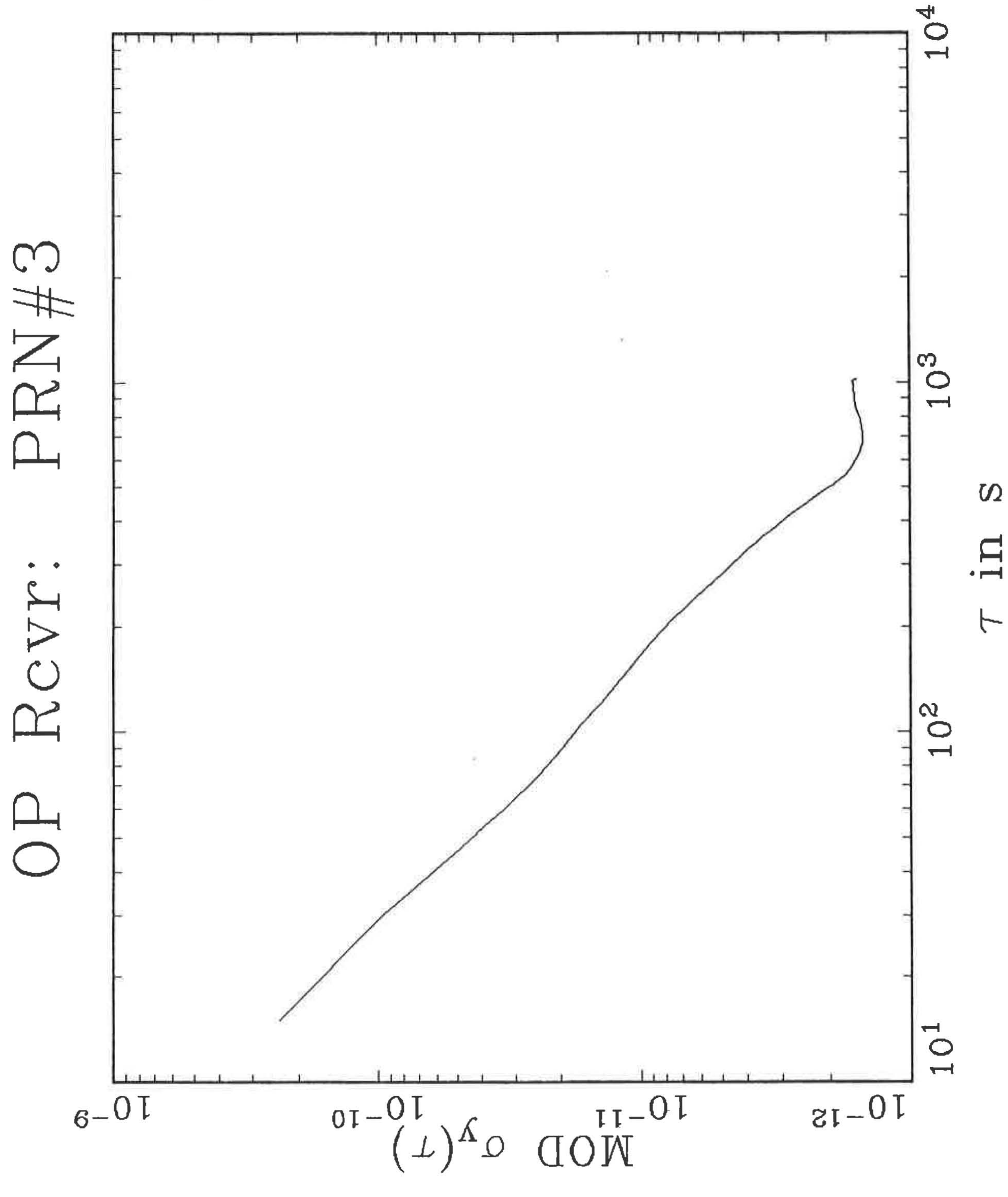

OP Rcvr: PRN#3
MOD $\sigma_y(\tau)$
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^1
10^2
10^3
10^4
τ in s

Fig. 9

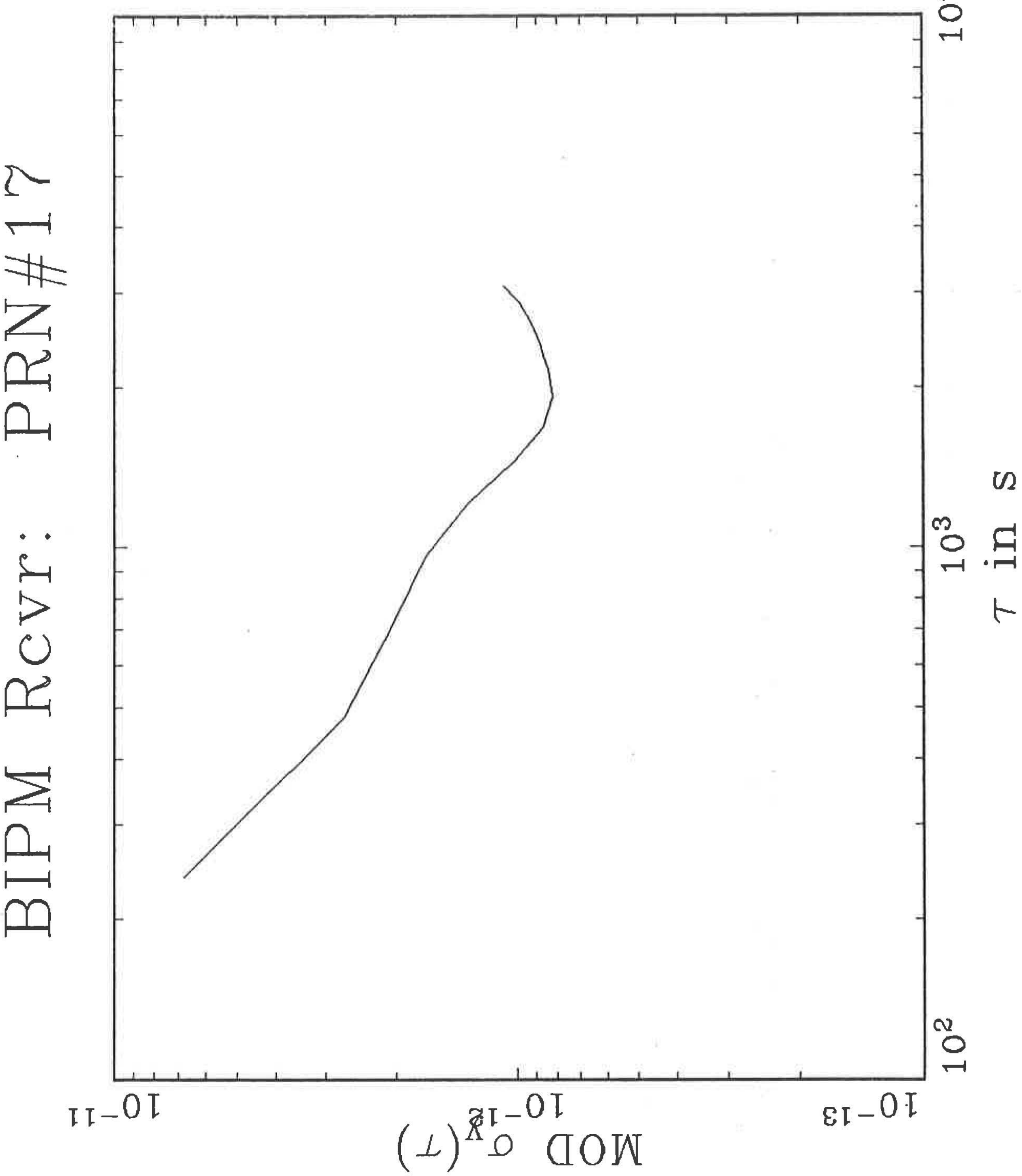

BIPM Rcvr: PRN#17
10^{2}
10^{3}
10^{4}
τ in s
10^{-11}
10^{-12}
10^{-13}
MOD $\sigma_y(\tau)$

Fig. 10

Imprimerie Durand
B.P. n° 69 – 28600 Luisant – 37 24 48 00
Dépôt légal imprimeur n° 7263
2e trimestre 1990