19. ROTATION OF THE EARTH
(ROTATION DE LA TERRE)

PRESIDENT: R.O. Vicente
VICE-PRESIDENT:P.E. Pâquet
ORGANIZING COMMITTEE: H.J.M. Abraham, P.L. Bender, B. Elsmore, H. Enslin, K. Lambeck, C. Sugawa, G. Teleki, Ya. S. Yatskiv, G.M.R. Winkler, S. Yumi (ex officio)

The commission deeply regrets the deaths of our colleagues which were reported in the several circular letters issued during the last three years.

Introduction

The past three years have seen again a great development in the studies concerned with the rotation of the Earth, specially associated with the new techniques employed in these researches. There has also been a growing interest in the investigation of relationships between the dynamics of the Earth, around its centre of mass, and associated geophysical phenomena.

This report cannot give a complete picture of our rapidly expanding field of research because not only of the limited space available but also the lack of knowledge about all the researches in progress during the last three years.

The proof that the rotation of the Earth arises the interests of the astronomical community is the high attendance and large number of scientific papers at the IAU Symposia held during this period: the Symposium No. 78 "Nutation and the Earth's Rotation" in Kiev (USSR, May 1977), and the Symposium No. 82 "Time and the Earth's Rotation" in San Fernando (Spain, May 1978). This is an opportunity to place on record the appreciation of all participants to our colleagues of the local organizing committes for the excellent arrangements made.

The publication of the collected papers of Sir Harold Jeffreys (1977), who has had such an outstanding influence on the problems dealt by our commission, has been completed during the period of this report.

The bibliography of the scientific works of the late N. Stoyko has been prepared by A. Stoyko and will soon be published. A considerable number of the papers deal with the rotation of the Earth and connected problems.

The fact, that a large number of astronomers and geophysicists have lately been interested in the problems connected with the rotation of the Earth, has resulted in a number of misunderstandings in the definitions adopted in this field, and the difficulties have been pointed out by Melchior (1977).

In this report, the word "secular" has been avoided because we do not yet have a good enough theory that can forecast polar motion for, at least, several centuries; it also happens that our more reliable observations do not cover a century. We cannot forecast the behaviour of the Earth for intervals spanning some centuries (Vicente, 1977). The word"wobble" has not been employed, and such a word was never written in the very good classical treatises dealing with this subject and published in the main european languages.

It is registered, with satisfaction, the number of working groups that have been set up during the last three years, and dealing with particular subjects of the rotation of the Earth.

https://doi.org/10.1017/S0251107X00010701 Published online by Cambridge University Press

We have the following: 1) working group on the nutation (chairman P.K. Seidelmann) dealing with the definitions and adopted values for the nutations (free and forced); 2) working on the determination of the rotation of the Earth (chairman G.A. Wilkins) set up in order to promote a comparative evaluation of the techniques for the determination of the rotation of the Earth, and to make recommendations for a new international programme for observation and analysis in order to provide high quality data for practical applications and fundamental geophysical studies; 3) working group on mean latitudes (chairman B. Kolaczek) trying to analyse the observations of the stations employing classical techniques.

The working group on pole coordinates (chairman S. Yumi), set up in 1970, is finishing its task of computing the pole coordinates in a consistent system, since the beginning of the ILS (1899). The results obtained will be published soon by the International Latitude Observatory of Mizusawa. The actual computations were made at Mizusawa Observatory and entailed an enourmous amount of work successfully finished.

Changes in instrumentation

Lists of the instruments collaborating in regular international programmes are published in the Annual Reports of the IPMS and of the BIH.

Richmond: the PZT 6 has been installed
Ukiah: construction has begun on PZT 8 to be installed at this station
Hamburg: a new PZT is under construction and will be installed at the same latitude but far outside the city.
San Fernando: the astrolabe is being improved and transformed to a full pupil instrument.
Kitab: the PZT is in operation since the beginning of 1978.
Simeiz (Crimea): the Danjon astrolabe is operating since May 1978. The Intercosmos laser tracking system is also in operation.
Mizusawa: the upper Talcott level of the VZT was replaced by the Tsubokawa's electromagnetic level. Thenew PZT was covered with a vertical wind tunnel having double mouths over the objecive in order to avoid thermal convective disturbance through the optical path.

Research in instrumentation

The work on the first mobile zenith camera continnes (Pilowski, 1976). An experimental equipment for the photoelectric registration of star transits with a PZT was successfully tested by Meinig and Long (1977). The new PZT, at Hamburg, will differ in essential parts from the present PZTs; it is a 60 cm Schmidt telescope, and the relation to the vertical will be established by means of a hanging flat mirror.

All of the electronic control system of the Greenwich PZT has been replaced during the period of this report. The measurement of the plates has been made semi-automatic; image positions are now monitored and recorded by a computer linked to the measuring machine, and this has speeded up the reductions without loss of accuracy.

The Pulkovo Observatory continned observations with the two photoelectric transit instruments of the new type during 1976-78.

Astronomical refraction

The U.S. Naval Observatory is cooperating in a project of D. Currie (Univ. of Maryland) to investigate the possibility of determining corrections for the effect of refraction on the classical observations of time and latitude. The anomalous refraction was studied by Teleki (1977). Refraction anomalies were also studied by Dittrich (1976).

A refraction formula was proposed by Sugawa and Kikuchi (1975), taking into account the effects of the total air mass, due to different scaleheights, and of the anomalous refraction due to the tilting of the air strata. A computation method of the astronomical refraction is applied, by Takagi and Goto (1975), to the data obtained from the radio sonde observations.

Revision of observing catalogues and of earlier observations

A new system of PZT catalogues for the Richmond and Washington instruments was developed and has been in use since January 1978. The new Washington catalogue makes use of Mizusawa PZT observations as well as past Washington observations, and it will serve as the basis for the newly-chosen observational programme of PZT 7. The observations of Mars with PZT 2 at Richmond have been analyzed by Babcock (1978) to determine the effects of chromatic aberration on the PZT observations as well as to determine corrections to the PZT catalogue and possible improvements to the Mars ephemeris.

The first Mizusawa PZT catalogue was improved by Takagi et al. (1976) based on 16 years' observations. The results of observations of Mizusawa PZT No. 1 and Danjon astrolabe OPL 34 were revised, based on the above newly determined corrections.

At Pulkovo, the catalogues in right ascension for 3 photoelectric transit instruments are under compilation covering the period 1963-75. New reductions and analysis of latitude observations with the Kazan VZT (1957-76) have been carried out by V. Lobanova.

Some earlier series of observations of latitude at the National Observatory (Rio de Janeiro) have been reduced (Barreto, 1978).

Research in problems concerned with the rotation of the Earth

A. FREE EULERIAN NUTATION (CHANDLER PERIOD)

The analysis of 18 years of latitude observations with the Paris astrolabe (Chollet and Débarbat, 1976) has confirmed the values of the principal terms of the polar motion but there are still some oscillations that need to be explained. The results of latitude determinations, obtained with the Potsdam astrolabe, show variations with time for the mean latitude of Potsdam as well as for the amplitude and phase of the Chandler, annual and semi-annual periods (Hopfner, 1977).

Nicolini is working on an improved analysis of the ILS data since 1900.0 for the deduction of the main periodic components of the polhode in a more uniform system, adopting the CIO as the common origin.

Ooe and Goto (1976) estimated the monthly excitation function of the Chandler period, using IPMS, BIH and Doppler satellite data. Assuming random excitations, Sekiguchi (1977) deduced some statistical relations between the polar motion and the excitation functions.

Popov and Yatskiv (1977) determined the maximum entropy power spectrum of the differences of latitude derived from the observations of two bright zenith stars at Poltava. The observations at Pulkovo with the zenith telescope ZTF-135 during 1948-67 were analysed and Chandler's period was found to be 1.192 years.

Feissel is analysing, by Burg's method, the noise of the pole coordinates published by the ILS, IPMS, BIH and DMA (1969-75). She is also preparing the revision of the results in x, y, UT 1 obtained by the method employed by the BIH since 1962.

B. FREE NEARLY DIURNAL NUTATION

Yatskiv has presented a review to the IAU Symposium No. 78 concerning the determination of this nutation from latitude and time observations. Sekiguchi (1978) analyses the causes of the excitations of this nutation.

C. FORCED NUTATIONS

The length and homogeneity of the observational series of Paris astrolabe has shown the need to correct certain terms of the nutation (Capitaine et al., 1977). Some conclusions have been obtained recently by Débarbat (1978) referring to the principal term of the nutation.

Fedorov has presented, to the IAU Symposium No. 78, the review paper concerning the determination of nutation coefficients from astronomical observations. Tarady and Korsun (1977) analysed the fortnightly terms in latitude observations of the ILS stations (1935-55).

Yokoyama et al. (1977) evaluated the amplitudes of the principal, the semi-annual and the annual nutations from the Z-term in latitude variation and the τ-term in longitude variation of the IPMS system.

Fleckenstein is determining values of the constants of nutation and aberration, employing latitude observations of the Neuchâtel PZT.

The Centre for Astronomy and Space Sciences of Bucharest has continued the researches about the separation of the periodic components in the motion of the instantaneous rotation pole. Dramba has studied the relations between the positions of the poles of rotation and figure.

D. LONG-PERIOD MOTIONS OF THE POLE

Markowitz has analysed IPMS and Doppler data that show long-period motions similar to the average of ILS since 1900.

Vicente and Currie (1976) analysed the maximum entropy spectra of various sets of ILS-IPMS data which show a strong signal at 29.8±2.3 yr and which was interpreted as a long-period term in the complex polar motion.

Yatskiv et al. (1978) showed that the 20-year periodical component in polar coordinate could be explained by the effect of non-polar latitude variations of stations, in particular, Ukiah station.

Abraham has been engaged in investigating the free and long-period motions of the pole.

E. CHANGES IN THE RATE OF THE EARTH'S ROTATION

Determinations of A.1-UT2, made at the U.S. Naval Observatory since 1955, were analysed by McCarthy and Percival (1978). The results indicate that the Earth may be subjected to random rotational accelarations occurring with a frequency greater than once per year. The suspected "irregular" variations in the rotational speed, occurring over intervals of one to ten years, reflect the accumulation of the random accelerations which occur with a higher frequency.

Iijima et al. (1978) clarified relations among periodic terms which appear in the results of time and latitude observations of the Tokyo PZT during the past 15 years. Okazaki (1977) ascribes the short-term irregular variations in the Earth's speed of rotation, observed from 1957 through 1964, to the irregular change of the global zonal wind circulation mainly in the tropical zone.

https://doi.org/10.1017/S0251107X00010701 Published online by Cambridge University Press

Korsun and Emetz have calculated the maximum entropy spectrum of $A\omega/\omega$ during 1900-74 and have found periods of 22 and 57 years. Sidorenkov (1978) has determined the monthly values of the relative angular momentum of the atmosphere and the corresponding values of the variations in the rate of the Earth's rotation during 1956-77.

The analysis of lunar laser ranging (LLR) data provides values of UTO at McDonald Observatory with typical accuracies of less than 1 ms for individual days. An analysis of 300 UTO values over 5 years has been published (Harris and Williams, 1977). A study of 500 values spanning 7 years shows that the differences UTO (LLR) - UTO (BIH) have a prominent 1.8 ms annual term as well as systematic drifts of several ms over the 7 years. For the component of polar motion parallel to the longitude of McDonald Observatory, the BIH 5 day smoothed values are found to have a random rms error of 25 cm.

F. EARTH TIDES

The analysis of the latitude observations of the Paris astrolabe has permitted the determination of the value Λ by Capitaine et al. (1977).

Gubanov and Yagudin (1978) determined the Love number k from the periodic waves M_m and M_f of UT1 for the years 1955-74. They also found the combination Λ from the wave M_2 of UT1.

Saito (1978) found a relationship between tidal Love numbers and load Love numbers. The theory is being extended to calculate partial derivatives of Love numbers with respect to the density and elasticity.

Polar motion determinations from Doppler observations

Anderle (1976a) compares the pole position results obtained by ILS, BIH and DMA (Doppler), discussing possible long-period drifts and presenting error statistics for the years 1964 to 1975. Anderle (1976b) gives a detailed account of the procedures involved in obtaining pole positions from Doppler data; he finds that the standard deviation of a five day mean position is about 25 cm. In May 1978, Oesterwinter(1978) states that this standard deviation is now down to 20 cm, due in part to more observations than in previous years. He finds the Chandler period to be 432$\pm$0.2 days.

The Doppler station of the Royal Observatory of Belgium takes part in the observations of the MEDOC network since January 1977. Decided to continue this effort, the Observatory (Pâquet, 1978) has just bought new observing equipment. Besides the observations, the Observatory develops computation programmes that permitted the determination of station coordinates from a precise ephemeris, and 37 stations were localised in Europe (Usandivaras et al.,1976). The second step, at the moment, should allow the determination of a precise orbit with the following particularity: nowadays the stations send the raw observations to a compunting centre (Bureau Central) which has the task of performing all the computations. This method imposes difficulties for the transmission of data and entails a considerable amount of work for the Bureau Central. Pâquet and Devis (1978) are trying to establish an analysis such that the stations make the greater part of the preliminary computations, in order that the transmission of data will be reduced to a minimum and the Bureau Central shall not deal with the observations.

Doppler positioning is made at the Latitude Observatory of Mizusawa using a single pass observations with the aid of precise ephemeris during 1976.0-1977.5 (Takagi, 1977).

Polar motion determinations from radio-astronomy

The following report has been prepared by B. Elsmore:

https://doi.org/10.1017/S0251107X00010701 Published online by Cambridge University Press

Several radio astronomy groups have indicated an intention of making regular measurements of earth rotation and polar motion with an expected accuracy of about ± 2 ms for UT1 and the pole to about ± 10 cm or better. These include the USNO/NRL group who will use the 35-km connected interferometer, and later, the "Very Large Array", as reported by Johnston (1978). The VLBI group using the Haystack, Massachusetts to Owens Valley, California baseline have some preliminary results, but are planning to dedicate a 3-Station network to provide a regular service by 1980-1981, as reported by Carter et al. (1978). At Symposium No. 82, Fanselow et al. (1978) of the Jet Propulsion Laboratory reported their plans for a VLBI network spanning U.S.A., Australia and Spain; the installation expected to be complete by 1979.

A most positive step forward is to be expected arising from the formation of an IAU working group, under the Chairmanship of G.A. Wilkins, to consider the merits of the new techniques, including radio astronomy. The working group are expected to make plans for periods of intensive observations, using many different techniques and instruments, and for the subsequent intercomparison of the results achieved.

Polar motion determinations from laser observations

Laser tracking of the Lageos spacecraft has been used to derive the position of the Earth's pole of rotation at 5-day intervals during October, November and December 1976. The estimated precision of the results is 0.01 to 0.02 arcseconds in both x and y components, although the formal uncertainty is an order of magnitude better, and there is general agreement with the Bureau International de l'Heure smoothed pole path to about 0.02 arcseconds. Present orbit determination capability of Lageos is limited to about 25 cm rms fit to data over periods of 5 days and about 50 cm over 50 days. The present major sources of error in the perturbations of Lageos are Earth and ocean tides followed by the Earth's gravity field, and solar and Earth reflected radiation pressure. Ultimate accuracy for polar motion and Earth rotation from Lageos after improved modeling of the perturbing forces appears to be of order ± 5 cm for polar motion over a period of about 1 day and about ± 0.2 to ± 0.3 milliseconds in U. T. for periods up to 2 or 3 months (Smith et al., 1978).

Schutz and Tapley (1978) have derived interesting polar motion results from laser range measurements of Geos-3.

Lunar ranging data have been routinely available since September of 1970, but many problems of a varying nature have delayed the establishment of a world-wide lunar ranging network. As a result, we must reexamine the role which this program can play in the determination of the Earth's rotation and polar motion. Although there are many technical difficulties now inhibiting the widespread use of this technique there seems little doubt but that we can overcome these problems and achieve routine, accurate orientation determinations. The more difficult questions concern how an Earth rotation campaign should now be configured to use the equipment and resources in the best way.

Despite considerable progress by other techniques, the failure to develop a lunar capability for Earth orientation determinations would result in a serious loss of information. Lunar monitoring of long-term effects in the Earth's rotation rate and the relationship of the lunar orbital parameters to a stellar reference frame are two tasks for which there is little redundancy. However, the most cost-effective usage of station resources may not require daily measures, but only periodic, accurate snapshots of the Earth's rotational position relative to the Moon. If some satellite laser ranging facilities could treat the Moon as an object of opportunity, but were able to elevate the program to priority status when global conditions were favorable, the incremental cost of gathering the required lunar data might be drastically reduced. Even though these cost savings could not be achieved

https://doi.org/10.1017/S0251107X00010701 Published online by Cambridge University Press

without daily communication between cooperating stations, such a detailed interaction is not unreasonable to consider (Silverberg, 1978).

Several new "space" techniques have been used for episodic determination of Earth rotation parameters, usually the variation in apparent longitude (UTO) and apparent latitude of an observing station. Earth rotation services require more than episodic determinations; they need near-daily determinations. Since 1975, planning has been underway for a demonstration of the viability of lunar laser ranging for such a usage. The observing campaign named Earth Rotation from Lunar Distances (EROLD) was organized with the proposed activity to cover the years 1977-78. Progress has not been so rapid as hoped, but it remains true that lunar ranging has produced more Earth rotation information than other new techniques. The goal was not just to make episodic determinations of the Earth rotation parameters, but to try to meet a regular and frequent schedule, such as those now followed by the BIH and the IPMS networks (Mulholland, 1978).

The laser station of CERGA, at Grasse, will be able to track all classical geodetic satellites; including geostationary satellites. Results have been recently obtained on Lageos satellite. The station should be operational in 1979.

Relations with geophysical phenomena

Zharkov and Molodensky (1977) have determined the corrections to the Love numbers caused by viscosity of the mantle. Pariisky (1978) pointed out the possibility of correlation between the variations in the rate of the Earth's rotation and the variations of gravity. This communication is based on another paper (Molodensky et al., 1977). A dependence of the amplitudes, of Chandler and annual pole motion of the Earth, on the solar activity was investigated by Kostina and Sakharov (1977). Sheptunov (1977) deals with the causes of non-polar latitude variations.

Jochmann (1976) continued his researches about the excitation of polar motion, showing that the annual period has meteorological origin mainly as a result of air mass shifts. Brosche and Sundermann (1978) have continued their studies on oceanic paleo-tides and their effects on the rotation of the Earth.

The deflexions of the local vertical at the frequency of the M_2 tide, as given by PZT observations at Greenwich, have been compared with predicted values that incorporate new calculations of the gravitational attraction due to M_2 tides in the surrouding seas (O' Hora , 1978).

Variations of differences of latitude and of stations located in the vicinity of a common meridian have been studied by Kolaczek et al. (1977). Analysis of non--polar variations of geographic latitude (Rogowski, 1978) and latitude changes (Jakš, 1978) have been carried out in Poland. Opalski (1978) worked on the random excitation and damping of polar motion.

Rochester (1976) studied the effect of inertial and dissipative (electromagnetic and viscous) core-mantle coupling on the Earth's precession. Sasao et al.(1977) dealt with the dissipative core-mantle coupling and nutational motion of the Earth.

Report of the Bureau International de l'Heure

This report covers only the BIH activities on the rotation of the Earth; the activities on atomic time are presented to Commision 31.

During the last three years, the BIH continued to compute and to make available the values UTI-UTC, and the coordinates of the pole, without important change.

UT1 is still based on the data of astrometric instruments only; the number of participating instruments being practically stable. The coordinates of the pole are based on astrometry and on the results of the Defense Mapping Agency (USA) obtained from Doppler Observations of Transit satellites. The Dppler data continue to improve and they are now much more precise than the data deduced from the whole set of astrometric instruments; their weight was therefore increased in the BIH computations. The standard deviation of the raw values of UT1, x, y computed every 5 days is typically of the order of 0.0008s, 0".007, 0".007.

On account to the improvement of the precision, the problem of the accuracy of the BIH results has a growing importance . When initiating the BIH system in 1967/68, there was no means to calibrate the annual terms in UT1 and in the coordinates of the pole, which were therefore affected by the annual errors of the contributing observations at that time. The BIH methods were devised in order to keep the annual errors of UT1, x and y as constant as possible. The comparison with Doppler shows that this was fairly well realized, for the coordinates of the pole; but the annual differences reach, peak to peak, about 0".04 for x, 0".02 for y. Although we believe, at the BIH, that the annual error lies in the BIH system, rather than in the Doppler data, we desired to wait until the Doppler data are confirmed by other new techniques, before modifying our system by an annual correction. However, in view of the delays in the implementation of these other techniques, it could be appropriate not to postpone further this modification.

The BIH results are reported in monthly Circular D and in the BIH Annual Report. The Report gives now the angular velocity of the rotation of the Earth (in radians/second) and the duration of the day, 5-day values and yearly means. It was attempted to discontinue the Circulars A (giving UT2-UT1) and B/C (giving UT1-UT0, observed and predicted), but inquiries have shown that these Circulars are still needed. It was also attempted to discontinue the publication of the raw observations and residuals (annual liflet) which is very expensive and to replace it by sending the data under machine readable form, on request; but the printed data appear to be still required.

In addition to its normal service, giving the results on the rotation of the Earth every month, with a delay ranging from 1 to 2 months, the BIH continues to operate a rapid service for the needs of space research (under a contract of the Jet Propulsion Laboratory): on Thursdays the data covering the preceding week are sent by teletype to several agencies. An increasing number of participants to this rapid service is noted; in particular, the quality of the UT1 results was greatly improved by the participation of all the USSR observatories measuring UT1, through the Gosstandard.

The BIH is involved in the projects MEDOC and EROLD. MEDOC is an attempt by the French Groupe de Recherche de Géodésie Spatiale to operate an international Doppler network for deriving the motion of the pole. The BIH helped in organizing the network and by the scientific activity of some members of its staff. The participation of the BIH to EROLD (Earth rotation by lunar distances) is possible thanks to the collaboration of the team of CERGA (France); it will consist in deriving UT1, x and y from the lunar distances as soon as they will be measured in several locations.

In order to take advantage of the revised data on UT0 and latitude prepared by several observatories and the experience gained in the BIH computations, it was decided to undertake a recomputation of UT1 and of the coordinates of the pole since 1962. The work is in preparation under the responsability of M. Feissel.

The BIH is represented by M. Feissel in the working group created by the IAU Symposium n° 82, to prepare the transition from astrometry to new techniques in the measure of the rotation of the Earth.

B. GUINOT

Director.

https://doi.org/10.1017/S0251107X00010701 Published online by Cambridge University Press

Report of the International Polar Motion Service

Annual Report of the IPMS for the years 1974, 1975 and 1976 were published during these three years. In those volumes are included the coordinates of the pole deduced from all the latitude and time observations reported to the Central Bureau of the IPMS in addition to the ILS data. Several kinds of polar coordinates are given in these volumes, that is, $IPMS_L$, $IPMS_{T+L}$ with and without τ-term and ILS.

All the observations of the ILS for the period during 1955 - 1966 were recalculated at the Central Bureau of the IPMS and published by Yumi and Yokoyama(1978). After the same method of calculation adopted in the Vol. XII, all the observations during 1967 - 1977 were also recalculated by I. Sato et al. (1978). The coordinates of the pole in the ILS system given in the above two publications for the period during 1955 - 1977 show remarkable discrepancy with those published already in the Results of the International Latitude Service, Vol. XI (G. Cecchini 1973, Firenze, Italy) and the Annual Report of the IPMS (1962 - 1976). The discrepancy with annual feature is clearly due to insufficient correction to the provisional micrometer constants applied in the past volumes. The new method for detecting variation of the micrometer values was devised and adopted in the Vol. XII, which made it possible to exclude spurious annual variation in latitude due to improper micrometer values.

The project of recalculation of all the ILS observations from 1899 in a uniform system is now coming to the goal. Less than 0.02% of the observations show large dispersions from the average values, which are probably due to misrecords of the observers. After judging whether these observations should be rejected or corrected, magnetic tape data of the original observation books will be completed. Preliminary coordinates of the pole from the beginning of the ILS have already been evaluated principally after the method adopted in the Vol. XII of the ILS, and they were compared with the past values given in the past reports of the Central Bureau of the ILS. The results of comparison reported by Yumi et al. (1978) showed that there exist remarkable discrepancies between the new and the old values of the coordinates of the pole, which have generally annual feature and are clearly due to the variation of the micrometer values. The final values of the coordinates of the pole from beginning of the ILS will be published soon.

Various kinds of data are now available in MT base. These are; i) original records of observations, ii) individual latitudes based on the Melchior-Dajaiffe Catalogue, iii) individual latitudes corrected for the declination and the proper motion errors. These data, including any data else, will be delivered on request.

S. YUMI
Director

References

Anderle, R.J.: 1976a, "Naval Surface Weapons Center", TR-3464, Dahlgren
Anderle, R.J.: 1976b, Bull. Geodes. 50, p. 377
Babcock, A.K.: 1978 "Photographic Zenith Tube Observations of Mars" (Univ. Virginia Master's Thesis).
Barreto, L.M.: 1978 IAU Symp. 82, in press
Brosche, P. and Sundermann, J: 1978 IAU Symp. 82, in press
Capitaine, N., Chollet, F. and Débarbat, S.: 1977 IAU Symp. 78, in press
Capitaine, N., Chollet, F. and Débarbat, S: 1977 Communication presented in Bonn meeting, in press
Carter, W.E., Robertson, D.S. and Abell, M.D.: 1978 IAU Symp. 82, in press
Chollet, F. and Débarbat, S.: 1976 Mitt. Lohrmann Obs. 33, Dresden
Débarbat, S.: 1978 IAU Symp. 82, in press
Dittrich, J.: 1976 Veroeffentl. Zentralinst. Physik Erde 36, Potsdam
Fanselow, J.L., Thomas, J.B., Cohen, E.J., MacDoran, P.F., Melbourne, W.G.,

Mulhall, B.D., Purcell, G.H., Rogstad, D.H., Skjerve, L.J. and Spitzmesser, D.J.: 1978 IAU Symp. 82, in press
Gubanov, V.S. and Yagudin, I.I.: 1978 IAU Symp. 82, in press
Harris, A.W. and Williams, J.G.: 1977 in J.D. Mulholland (ed.) "Scientific Applications of Lunar Laser Ranging", D. Reidel, Dordrecht, p. 179
Hopfner, J.: 1977 Gerlands Beitr. Geophys. 86, p. 449
Iijima, A. Fujii, S. and Niimi, Y.: 1978 IAU Symp. 82, in press
Jaks', W.: 1978 Publ. Geophys. Inst. Polish Acad. Sci, in press
Jeffreys, H.: 1971-77 "Collected papers of Sir Harold Jeffreys on Geophysics and other Sciences", 6 vols., Gordon and Breach, London
Jochmann, H.: 1976 Veroeffentl. Zentralinst. Physik Erde 35, Potsdam
Johnston, K.: 1978 IAU Symp. 82, in press
Kolaczek, B., Galas, R. Barlik, M. and Dukwicz, M.: 1977 IAU Symp. 78, in press
Kostina, L. D. and Sakharov , V.I.: 1977 Solar Data. No. 5
McCarthy, D.D. and Percival, D.B.: 1978 IAU Symp. 82, in press
Meinig, M. and Long, N.T.: 1977 Vermessungstechnik 25, p. 370
Melchior. P.: 1977 IAU Symp. 78, in press
Molodensky, M.S., Molodensky, S.M. and Pariisky, N.N.: 1977 Bull Inf. Marées Terrestres 76, p. 4462
Mulholland, J.D.: 1978 IAU Symp. 82, in press
Oesterwinter, C.: 1978 IAU Symp. 82, in press
O'Hora, N. P.J.: IAU Symp. 82, in press
Okazaki, S.: 1977 Publ. Astron. Soc. Japan 29, p. 219
Ooe, M. and Goto, Y.: 1976 Publ. Int. Lat. Obs. Mizusawa 10, p. 163
Opalski, W.: 1978 Warsaw Techn. Univ. Prace Nauk Geod. Nr. 19
Pâquet, P.: 1978 in S. Hieber and T. Guyenne (eds.) "Space Oceanography Navigation and Geodynamics", ESA
Pâquet, P. and Devis, C.: 1978 Symp. 82, in press
Pariisky, N.N.: 1978 Proc. Int. Symp. "Non-tidal Variations of Gravity" in press
Popov, N.A. and Yatskiv, Ya. S.: 1977 Astr. Zh. 54, p. 429
Pilowski, P.: 1976 Astr. Station Tech. Univ. Hannover, Ergaenzung II , Nr. 10
Rochester, M.G.: 1976 Geophys. J. Astron. Soc. 46, p. 109
Rogowski, J.B.: 1978 Warsaw Techn. Univ. Prace Nauk Geod. Nr. 19
Saito, M.: 1978 J. Phys. Earth 26, p. 13
Sasao, T., Okamoto, I. and Sakai, S.: 1977 Publ. Astr. Soc. Japan 29, p. 83
Sato, I., Ishii, H. and Yokoyama, K.: 1978 Publ. Int. Lat. Obs. Mizusawa 12, p. 1
Schutz, B.E. and Tapley, B.D.: 1978 IAU Symp. 82, in press
Sekiguchi, N.: 1977 J. Geod. Soc. Japan 23, p. 17
Sekiguchi, N.: 1978 J. Geod. Soc. Japan 24, in press
Sheptunov, G.S.: 1977 Astrometrija i Astrozika 32, p. 74
Sidorenkov, N.S. 1978 IAU Symp. 82, in press
Silverberg, E.C.: 1978 IAU Symp. 82, in press
Smith, D.E., Kolenkiewicz, Dunn, P.J. and Torrence, M.: 1978 IAU Symp. 82, in press
Sugawa, C. and Kikuchi, N.: 1975 Proc. Int. Lat. Obs. Mizusawa 15, p. 1
Takagi, S.: 1977 Publ. Int. Lat. Obs. Mizusawa 11, p. 57
Takagi, S. and Goto, Y.: 1975 Publ. Int. Lat. Obs. Mizusawa 10, p. 41
Takagi, S., Murakami, G. Kitago, H. Sakai, S. and Iwadate, K.: 1976 Publ.Obs.Miz.10,p179
Tarady, V.K. and Korsun, A.A.: 1977 IAU Symp. 78, in press
Teleki, G.: 1977 Bull. Obs. Astron. Belgrade, No. 128
Usandivars, J. Pâquet, P. and Verbeiren, R.:1976 "Satellite Doppler Positioning",NOAA
Vicente, R.O.:1977 in J.D. Mulholhand(ed.)"Scientific Appl.Lunar Laser Ranging",p.143
Vicente, R.O. and Currie, R.G.: 1976 Geophys. J. Roy. Astron. Soc. 46, p. 67
Yatskiv, Ya. S., Korsun, A.A. and Mironov, N.T.: 1978 IAU Symp. 82, in press
Yokoyama, K., Ishii, H. and Sato, I.: 1977 Publ.Int. Lat.Obs.Mizusawa 11, p. 11
Yumi, S. and Yokoyama, K.: 1978 Results Int.Lat. Service (1962-67)12, Mizusawa
Yumi, S., Yokoyama, K. and Ishii, H.: 1978 IAU Symp. 82, in press
Zharkov, V.N. and Molodensky, S.M.: 1977 Physics Earth 5, p. 17

R.O. VICENTE
President of the Comission