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RECORD No. 1962/16

VISIT TO JAPAN, 1961

by

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SUMMARY

The writer visited Japan to attend the International Conference on Cosmic Rays and the Earth Storm at Kyoto in September 1961. Data from satellites, cosmic rays, geomagnetic and ionospheric recordings, whistlers, and airglow combine to give a broad picture of the solar-terrestrial relations involved in magnetic disturbances, but there are many features that still require explanation.

Visits were made to geophysical institutions in Japan, and some interesting developments in geomagnetic and gravimetric equipment were examined. Programmes and techniques for the World Magnetic Survey and the International Year of the Quiet Sun, as well as other research projects, were discussed with Japanese and visiting geophysicists. There was considerable interest in BMR activities at Macquarie Island, which is magnetically conjugate to Alaska.

1. INTRODUCTION

The main purpose of my visit to Japan in August and September 1961 was to attend the International Conference on Cosmic Rays and the Earth Storm, held in Kyoto. I took the opportunity to visit various geophysical institutions in Japan. This Record is divided into three parts: The first part deals with the geophysical institutions I visited in and near Tokyo; the second is devoted to a summary of some highlights of the conference itself; the third describes some meetings and informal discussions which were held in Kyoto, but which did not form part of the conference.

PART I

2. GEOGRAPHICAL SURVEY INSTITUTE

(Director : Dr Tsubokawa)

This is a department of the Ministry of Construction. It is responsible for geodetic and magnetic surveying, as well as some astronomical work, but not for continuous geomagnetic recording.

(a) Geomagnetism

The magnetic survey programme involves a network of about 60 first-order stations and several hundred second-order stations. The first-order stations are reoccupied every two years; observations are made continuously for two or three days. These are intended to give good secular variation control.

The field magnetometer has been designed by the GSI and built by Sokkisha Ltd. It consists of a search coil which can be rotated by hand, much the same as an earth-inductor. The coil is connected through sliprings to an amplifier located in a console. The search coil is mounted on a theodolite base to which is attached a small telescope and a Helmholtz coil. The amplified signal from the search coil is displayed on a meter mounted on the console, which stands about 1.5m from the detector. The position of the axis of rotation of the coil at zero signal indicates inclination and magnetic north. The intensities are measured by energising the Helmholtz coil, whose axis is parallel to the axis of rotation of the search coil. To measure H the axes are made almost vertical, and the field of the Helmholtz coil is varied until a null is read. A complete set of observations can be made very quickly.

For standardizing field instruments the GSI operates an observatory at Kanozan on Boso Peninsula, south of Tokyo. There they have proton precession magnetometers for measuring the three components of the field. The only novel feature is that the signal beats with a standard frequency, and the resultant beat note is recorded directly. For measuring components, a Fanselau vector coil is used. (A Fanselau coil has four elements, instead of two as in a Helmholtz coil, the inner pair of coils being of larger diameter than the outer pair). In this case the diameters are about 25 and 30 cm respectively. The coil former is made of marble. The detector is a cylinder 6 cm long. A polarizing field of 200 gauss is used. The signal is recorded for 1.5 sec after each polarization.

(b) Gravity

An interesting type of gravity meter is being developed. It consists of a 10-g mass suspended by three fibres mutually at right angles. Each fibre is part of a positive feedback circuit which keeps the fibre oscillating at its natural period. The period depends on the tension in the fibre. The gravitational force on the mass is given by:

$$(mg)^2 = T_1^{\,2} + T_2^{\,2} + T_3^{\,2}$$

where T_i is the tension in the i-th fibre. The frequencies, about 500 c/s, can be measured to 10^{-3} c/s, which gives an accuracy of about 5 mgal. It is planned to use it at sea, set in double gimbals. The GSI pendulum apparatus ordered by the Bureau was design by Dr Tsubokawa and is used in these laboratories. It will be described in the next section.

(c) Geodetic length standards

I saw the length standards laboratory where surveyors' chains are standardized. They have a number of standard rods. The length of the smallest is determined relative to the wavelength of cadmium light.

3. SOKKISHA LIMITED

The workshop of Sokkisha Ltd is close to the GSI. Their main business is making survey instruments. They also undertake special construction work, and do most of the instrument work for GSI. Many of Sokkisha's instruments have been designed by Dr Tsubokawa.

They are constructing a set of pendulums for the Bureau. The quartz pendulums were cast in June 1961 and allowed to age until September 1961. The electronics are scheduled to be finished in February 1962, and the whole instrument should be ready for calibration by March 1962. They advise that an operator should spend a month there for training in the use of the apparatus.

The apparatus consists of the pendulums themselves, a light source and photocell, a vacuum pump, a crystal frequency standard, a time signal receiver, and a recorder.

The crystals have two sets of heaters, one manually and the other automatically controlled. The automatic thermostat has a limited range; outside this range, manual control is necessary. The thermostat for the pendulums can be set to 10°, 20°, 30°, or 40° C. The ambient temperature should be 10° or less below the thermostat setting.

A light spot reflected from the moving pendulum, via the "stationary" pendulum, sweeps past a slit in a viewing screen onto a photocell. The resultant impulses are recorded together with time marks from the crystal oscillator. The amplitude of the pendulums must be read on the viewing screen every 5 minutes.

4. EARTHQUAKE RESEARCH INSTITUTE

(Director : Dr Nasu)

This is located at Tokyo University, although it is a government sponsored institution. All kinds of earthquake research are carried out, e.g. seismology, vulcanology, physical properties of rocks, and building construction.

In the basement of the ERI building at Tokyo University are mechanical accelerometers and velocity seismographs recording on smoked paper. They have a magnification of about 30. There is also a self-starting strong-motion seismograph, designed to operate if the others are overloaded. Seismographs with a magnification of ten thousand are located at Kakioka. They dare not increase the magnification or they would record more earthquakes than they could analyse.

In one of the laboratories two students were studying the magnetic properties of rocks. When I was there the rock being studied had a Curie point near zero degrees centigrade. It is interesting to speculate what effect such a rock could have on local anomalies in a cold climate.

Dr Rikitake and one student are the only members of ERI interested in geomagnetism. The interest in geomagnetism started with an attempt to measure magma movements in volcanoes by magnetic methods. Dr Rikitake's present work has little to do with earthquakes.

5. GEOPHYSICAL INSTITUTE OF TOKYO UNIVERSITY

(Director : Dr Nagata)

This is the biggest academic geophysical institution in Japan. Most of the leading young geophysicists in Japan are graduates of this Institute. It works closely with the Earthquake Research Institute, but the two are administratively separate. There are also geophysical institutes at the University of Kyoto and the University of Tohoku.

6. KAKIOKA OBSERVATORY

(Director: Dr Yoshimatsu)

The Meteorological Agency of Japan operates three magnetic observatories. The headquarters observatory is at Kakioka, about fifty miles north of Tokyo. The other observatories are at Memanbetsu, in northern Hokkaido, and at Kanoya, in southern Kyushu. The total staff is thirty-nine; of these, seven are at Memanbetsu and nine at Kanoya. About half the staff devote most of their effort to research.

The observatory evidently has some prestige, for the Director was able to persuade the nearby electric railway to use alternating current.

The fields of investigation at Kakioka are :

(a) Geomagnetism

(b) Earth currents

(c) Atmospheric electricity

(d) Solar observations

(e) Meteorology

(f) Seismology

(a) Geomagnetism

Geomagnetism is their most important activity. The normal-run recorders are of the Eschenhagen type except the Z variometer, which has a double fibre (Watson type) suspension. They have developed an alloy (70% Fe, 20% Ni, 10% Cr) with a high magnetic temperature coefficient. A piece of this is put in opposition to the main magnet so that the resultant moment is approximately that of the main magnet, but the temperature coefficient is approximately cancelled. The resulting coefficient is one gamma per degree.

They have two absolute magnetic standard instruments. One is a sine galvanometer which measures H only. The other is a Universal (Johnson type) coil magnetometer for measuring D, H, or I. They go to a great deal of trouble to measure the current accurately. The pyrex former on which the coil is wound is measured to an accuracy of one micron twice a year. Altogether the method seems to involve a great deal of wasted effort considering that they are about to build a proton precess magnetometer.

I was told that a comparison had been made between H measured by the Universal Magnetomer and a set of QHM sent from Rude Skov in 1959 with the following result:

(Rude Skov) - A56 (Kakioka) = + 6 gamma or + 20 gamma/gauss

An indirect comparison with the proton magnetometer of GSI indicates a difference of less than one gamma.

An air-cored induction magnetograph records at a speed of about ten millimeters per minute. Large loops are used for each element. Those for X and Y are buried in long thin trenches.

(b) Earth currents

North-south and east-west earth potential differences are recorded photographically by galvanometers and lines 1 km long. The recording speed is too slow and I imagine that the earth current recordings are less useful than those of the induction magnetograph.

(c) Atmospheric electricity

Atmospheric electric recording comprises atmospheric conductivity of both signs, potential gradient, using a water dropper, and ion counts. There was no evidence of an active programme of analysis of the results.

(d) Solar photography

Solar investigations consist of photographing the sun's surface from which counts of sunspots, flares, etc., are made.

(e) Meteorology

Meteorological observations are conventional and are made to help interpretation of atmospheric electric recordings.

(f) Seismology

The seismographs of the Earthquake Research Institute are located at Kakioka. No analysis is done there.

The chief interests of the research staff at the moment seem to be the design of the proton magnetometer and micropulsations.

PART II

7. COSMIC RAY AND EARTH STORM CONFERENCE

The conference was held at Kyoto from 4th to 15th September.

The name "Earth Storm" indicates a wider interest than simply fluctuations in the magnetic field. In fact, a feature of the conference was the emphasis on the influence of these storms on cosmic rays, the ionosphere, and outer space. This part of the Record attempts to summarise the highlights of the conference.

The conference itself was divided into three parts. The first dealt with earth storms, the third with cosmic rays, and the second with the common ground on which these subjects meet. In the account given here, however, that division will not be maintained.

8. SPACE RESEARCH

Some of the most interesting material presented at the conference dealt with the results of space research obtained by satellites and deep space probes. About 1955, Storey presented evidence derived from whistlers indicating that the space around the Earth was not empty but contained a plasma of electrons and positive ions. Storey estimated that the density of electrons in the vicinity of the Earth was about one thousand per cubic centimetre. Modern measurements indicate that this figure is too high by at least one order of magnitude.

During the flight of Explorer VI a magnetic storm occurred when the vehicle was about four earth radii from the centre of the Earth. At the surface of the Earth, at the equator, the field decreased by about 120 gammas during the main phase of the storm. At the space probe a decrease of 350 gammas was recorded simultaneously. This is direct evidence that the main phase of a magnetic storm is due to currents flowing outside the atmosphere.

An important result was reported by Rossi. Far from the Earth, space seems to be divided into regions of two types. In the first type the magnetic field has a magnitude of about ten gammas and its direction is irregular, and particle density is about 10 per cm^3. In the second type of region, the magnetic field has a magnitude of about twenty gammas and the particle density is very low, less than 0.2 per cm^3. The boundaries between these regions are quite sharp, rather like those which divide warm and cold air masses in the atmosphere. The dimensions of these regions are of the order of 10^{11} cm.

Several papers were presented about the Van Allen radiation belts. The density in these belts is not significantly different from that outside them. They differ only in that they contained a few very high-energy particles. Rather surprisingly the high-energy particles in the inner belt are protons and those in the outer belt are electrons. The origin of the inner belt appears to be cosmic ray neutron albedo (Neutrons formed in the upper atmosphere by cosmic ray collisions are scattered back into space and decay into protons and electrons, both of which are trapped in the Earth's magnetic field). There seems to be no simple explanation of the origin of the outer Van Allen belts. Neither belt has much connexion with magnetic storms, according to most authorities, although Chapman believes that the ring current is located in the outer belt.

The deceleration of satellites by the atmosphere is a delicate measure of atmospheric pressure. It has been conclusively demonstrated that the drag is greater during a magnetic storm. The maximum effect occurs at a height of 700 km. This agrees with the theoretical conclusions of Cole, who presented reasons for believing that joule heating of the ionosphere is important during magnetic storms.

9. OBSERVATIONAL GEOMAGNETISM

A great many papers on this subject were presented, and it is impossible even to mention all of them.

The most popular subject of magnetic investigations today appears to be micropulsations. Troitskaya claims that a magnetic storm has a definite pulsation structure, so that by looking only at the micropulsations it would be possible to determine when the sudden commencement, initial phase, and main phase took place.

Kato divides continuous pulsations into three types with periods of about 20 sec, 1 min, and 4 min respectively. The first type are what we normally call continuous pulsations, the second type have been called "giant pulsations", and the third type are what Jacobs and Troitskaya call LPC; this type is common in auroral zone magnetograms.

However, everyone agrees that these names are misleading and inaccurate. Father Cardus gave some examples of glaring inconsistencies in routine reporting of phenomena to Committee 10. Some observatories, e.g. those in Canada, have stopped reporting pulsations. The only useful results seem to be those which are based on the energy in each spectral interval, the determination of which requires spectrum analysis.

The importance of the comparison of conjugate points, especially in the auroral zones, is now realised. The high conductivity of the magnetosphere in the direction of the magnetic field means that conjugate points are electrically connected to each other. College (Alaska) and Macquarie Island form a pair of conjugate points, in fact the most accessible pair of conjugate points anywhere in the auroral zones. For this reason it is highly desirable that magnetic recording at Macquarie Island should increase in scope rather than decrease.

Jacobs presented a paper on short rapid variations (something like SI) which are often world-wide. He claims that 20 percent of all hourly intervals contain at least one such variation. They seem to be much more universal than the polar-storm type of bay. Chernosky presented some evidence indicating that the day preceding a storm is usually quiet. If this can be substantiated it may be of some importance because it suggests that the pre-storm calm is an integral part of the storm, which in turn suggests a continuous oscillation between storm and non-storm conditions.

10. IONOSPHERIC OBSERVATIONS

A large proportion of the ionospheric work related to polar black-outs. There are two distinct types. The normal sequence of events is an absorption confined to the polar cap (known as polar cap absorption or PCA). This does not coincide with bay-type magnetic disturbances. Later, when bay disturbances occur, absorption is confined to the auroral zone. Both of these phenomena are due to ionisation in the D-layer where the pressure is high enough to cause absorption of radio waves. Their effect is similar to that of the Dellinger fade-out but the mechanism of ionisation is quite different. The last is due to solar ultraviolet light and is confined to the sunlit part of the Earth. Furthermore, fade-outs last some tens of minutes whereas polar absorption lasts many hours.

Three techniques have been used for studying ionospheric absorption. The first and oldest is the recording of the minimum frequencies from ionograms. The second is the use of a riometer (Rio = relative ionospheric opacity) which is simply a receiver recording the amplitude of extra-terrestrial noise. The third is a high-frequency forward-scatter technique.

Two interesting airglow phenomena were reported. The first is a band of red light at magnetic latitudes 13° N and S. The radiation consists only of the 6300A light of atomic oxygen. The intensity is very closely related to the critical frequency and height of the F2 layer. During disturbances it becomes irregular and often decreases.

A somewhat similar red band of light occurs at geomagnetic latitudes 50° N and S. This also consists of the 6300A radiation. It has a much more transient existence than the tropical red band. The southern band has been seen from Camden. Australia and New Zealand are the only lands from which it is visible.

Lebadinsky presented evidence that auroral arcs extend continuously from Alaska right across Siberia to Murmask and that the entire arc moves northward or southward at certain times.

Knecht reported an interesting phenomenon which might be worth looking for in our ionograms. Occasionally during a fade-out, F2 critical frequencies increase suddenly by one Mc/s or more. This has been observed only occasionally and then only at stations where the real height of maximum ionisation is greater than 310 km. It appears to be connected with an increase in cosmic rays.

11. THEORY OF EARTH STORMS

The discussion on this subject was dominated by Singer, Parker, and Gold, with some comments by Hines, Alfvén, and others. In his opening address Chapman presented the theory that he and Akosofu recently developed.

In spite of the many differences of opinion that were expressed at the conference, there seems to be a core of agreement. It might be worth while to summarise this. The principal observed phenomena of a magnetic storm are a sudden commencement, an initial phase which consists generally of an increase in H, and a main phase which is a slower and larger decrease in H followed by a recovery during the following several days. These effects are most fully developed at the equator and are less conspicuous towards higher latitudes. Superimposed on this average variation are rapid bay-type fluctuations which are much more intense in high latitudes.

There is a considerable amount of agreement in the explanation of these broad features. The sudden commencement is considered to be due to a shock wave caused by a plasma cloud emitted from the sun. The initial phase is thought to be due to the compression of the geomagnetic field by the conducting plasma. The main phase is thought to be due to a ring current surrounding the Earth and flowing westwards. The charged particles forming this ring current have three types of motion. The first and most rapid is a rotation about the lines of magnetic force. The centre of rotation of each particle travels along the lines of force towards the Earth's surface until the magnitude of the field becomes so high that the particle is reflected and travels back to a similar "mirror point" in the other hemisphere. This oscillation is a feature of all modern storm theories. The gradient of the field causes a westward drift of positive particles and an eastward drift of negative particles which together form the ring current.

Some of the mirror points are sufficiently low in the atmosphere for collisions with air molecules to occur, and the particle is said to be precipitated (or "dumped") into the upper atmosphere. This happens in both auroral zones. In the ionosphere, above each auroral zone, a north-south electric field is developed. Owing to the anisotropic conductivity of the ionosphere the north-south electric field results in an east-west current. The circuit for this current is completed partly over the polar cap and partly over temperate latitudes. The magnetic effect of this current is the bay-like disturbance.

There is disagreement between the experts on several points. One is the importance of cosmic electric fields which (according to Alfvén) are due to the relative motion of plasma clouds and the Earth's magnetic field. The mechanisms of ejection of the plasma cloud from the sun and of the precipitation of particles from the ring current into the auroral zone are still in doubt. Cole suggested a positive feedback mechanism by which a small disturbance in the auroral zone can perturb the trapped radiation, thus depositing more particles into the auroral zone. Another point of contention is the amount of distortion of the geomagnetic field on the night side of the Earth. According to some authorities the solar wind drags the lines of force to a great distance on the side of the Earth opposite to the sun, and this may have important effects on the ring current. The mechanism of formation and decomposition of the ring current are also subjects of debate.

12. COSMIC RAY

In recent years the importance of cosmic ray studies to geomagnetism and related diciplines has increased.

Two cosmic ray phenomena have important geophysical implications. One is known as the "Forbush decrease". This is a decrease of cosmic ray flux measured at the surface of the Earth. It commonly occurs during a magnetic storm. An important discovery was made by the space probe Explorer V. At a distance of almost a million kilometers from the Earth a Forbush decrease was observed at the same time, and of the same intensity, as that observed on the Earth. This indicates that the Forbush decrease is a heliocentric rather than geocentric phenomenon. The second cosmic ray event is much rarer. It is an increase in flux, particularly in neutron counts. It has been observed only 14 times and never at sunspot minimum. It was observed twice during the last sunspot cycle and 12 times during the current cycle. The additional particles are thought to be high-energy protons originating on the sun. Some people do not like the term "cosmic rays" to be applied to these particles.

PART III

13. INTERNATIONAL YEAR OF THE QUIET SUN (IQSY)

A meeting of delegates interested in IQSY was held in Kyoto during the conference. No definite decisions were made and very little which is not already contained in CIG circulars was presented. There was some discussion about the duration of the interval. Most people seemed to prefer the 20 months as originally suggested, with periods of special emphasis. It was generally agreed that the discipline of meteorology should be included in the project. Chapman remarked that more information was required about the Sq field, especially over the Pacific Ocean. He claimed that induction effects are less there than in other regions.

National committees for IQSY had been formed in the USA, USSR and Japan. A calendar of world dates and special intervals will be produced.

14. WORLD MAGNETIC SURVEY (WMS)

An informal meeting of delegates interested in the World Magnetic Survey was held in Kyoto; Dr Vestine was chairman. Little was said about land surveys. Two major projects are planned for WMS. One is called POGO (polar orbiting geophysical observatory) which is to be a low-level satellite covering all parts of the Earth. The second is called EGO (eccentric geophysical observatory). This is a satellite with low perigee and high apogee. It is intended to measure the radial gradient of the magnetic field.

Airborne measurements under Project Magnet and ocean observations by the _Zarya_ will continue.

Dr Vestine has written a WMS manual which should clarify many requirements.

The IGY World Data Centres will be asked to handle WMS data.

15. DISCUSSION WITH DR WHITHAM

Dr Whitham of the Canadian Dominion Observatory was surprised to learn that we have started automatic trace scaling. They have plans for making a trace scaler with mechanical integration and an automatic read-out each hour.

Most regional magnetic work in Canada is now done by aircraft. Secular variation stations, of which there are about two hundred, are occupied on the ground for two or three days every few years.

They use proton magnetometers for special projects but do not use them for observatory standardizations. They plan to make a completely automatic observatory using proton magnetometers recording directly onto paper tape. The main difficulty is finding a sufficiently reliable switching mechanism. They tried a small four-element vector coil but without success, and have now changed to a large Helmholtz coil. They use toroidal samples and polarising coils.

16. DISCUSSION WITH DR R.R. BROWN AND DR V.P. HESSLER

Dr Brown of the University of California will visit Macquarie Island for three months early in 1962. He intends to set up an earth current system which, possibly, can be kept operating for the rest of the year. He is interested in conjugate point experiments using Macquarie Island and the Alaskan observatories, particularly College. He emphasised the need for higher-speed recording at Macquarie Island, and offered to help financially if this were necessary.

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