nence remaining nearly constant; and (iii) a strong increase in remanence of all coercivities above about 900°C. Secondary magnetite and hematite production may account for (i) and (iii), which are not seen in synthetic hematites. Process (ii) seems to be related to structural changes in the hematite and can be readily explained (as for the synthetic material) on the basis of a defect remanence that is softer than the spin-canted remanence.

Present evidence, therefore, favors the view that the ferromagnetism of red sediments, like that of synthetic fine grains but in contrast to that of single crystals (*7*), consists of a very hard fundamental moment and a softer structure-sensitive moment. If so, thermal demagnetization will preferentially destroy the defect moment, both because the average coercivity and hence the average blocking temperature of its NRM are lower than those of the spin-canted NRM and because the moment itself will partially anneal out. Thermal cleaning should then be very effective in eliminating magnetic noise from red beds, and experience suggests that it is.

It is worth pointing out that magnetoelastic anisotropy, like the defect moment, decreases as a result of the annealing inherent in thermal demagnetization. Fortunately for paleomagnetism, a disastrous total demagnetization of the NRM is prevented by the persistence of coercivities, apparently of crystalline origin, of the order of 100 oersteds throughout the blocking temperature range. The origin of a much larger crystalline anisotropy in fine grains than in large ones is, however, still unexplained.

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Satellite Observations of Lightning

Abstract. *Analysis of the positions of nighttime thunderstorms as determined from the detection of optical radiation by satellite OSO-B reveals that ten times as many lightning storms occur over land areas as over the sea.*

Pierce (*1*), Coroniti (*2*), and Larson *et al.* (*3*) have proposed that global thunderstorm activity be located by satellites. Satellite monitoring of radio frequencies was suggested as one method and has been implemented in Ariel 3 (*4*). As an alternative method it was proposed that optical observation of the 6563-Å hydrogen α-line be made.

We report here the observation of nighttime lightning activity from the orbiting solar observatory satellite OSO-B. During the experiment we monitored the light in the 10-deg field of view of four telescopes, three of which are suitable for the detection of lightning. The three photometers were sensitive to broad spectral bands. The time constants of the photometers were such that lightning strokes could be detected as a rapid increase in signal intensity followed by an exponential decay to background. A minimum light threshold of about 3×10^5 photon/cm^2 received at the satellite was set, below which lightning strokes could not readily be detected (*5*). Details of the experiment have been reported (*6*).

The data from the three photometers were initially scanned by computer (Control Data Corporation 6600) to separate out all abrupt increases, this data also being plotted to facilitate separation of those abrupt increases due to lightning from those due to other discrete sources (*7*) or bad data. The effectiveness of the selection was checked by comparison with data derived from the manual separation of lightning strokes which had been obtained earlier (*5*). The computer also calculated the time during which each 1 deg^2 on the earth's surface was in the field of view of the photometers for each orbit and then summed these times over 10-deg squares and all orbits to find the degree of uniformity of coverage (Fig. 1). In order to simplify the calculations, only those periods of time were considered during which the earth filled the whole field of view of any of the telescopes. This procedure also ensured that the accuracy in determining the position of each lightning stroke was better than approximately 3 deg in latitude and longitude.

Pierce (*1*) has suggested that the typical size of thunderstorm complexes and the frequency of lightning flashes effectively limit satellite detection to that of thundery regions rather than of individual thunderstorms. This suggestion has been followed here in the plotting of Fig. 2, which shows the positions of nighttime lightning storm regions observed by satellite OSO-B. Thunderstorms detected in the same location on successive days have been plotted separately, although, when storms were detected on consecutive orbits (96 minutes apart), only one point has been plotted. The accuracy in positioning each point is greater than that of individual lightning strokes when the storm region is indicated by a number of lightning strokes. Since the satellite coverage of the earth's surface was "relatively uniform" in bands of constant latitude (except in that region where data transmission took place), Fig. 2 may be taken directly as an indication of the nonuniformity of storm occurrences. The storms predominantly occur over land areas and the tropic island area north of Australia. The disparity between regions over or close to land and sea regions appears to be larger than a factor of 10. This result was surprising in view of the fact that Rasool (*8*), in a study of nighttime cloud cover from satellite observations, has not reported any similar disparity in the ratio of cloud cover

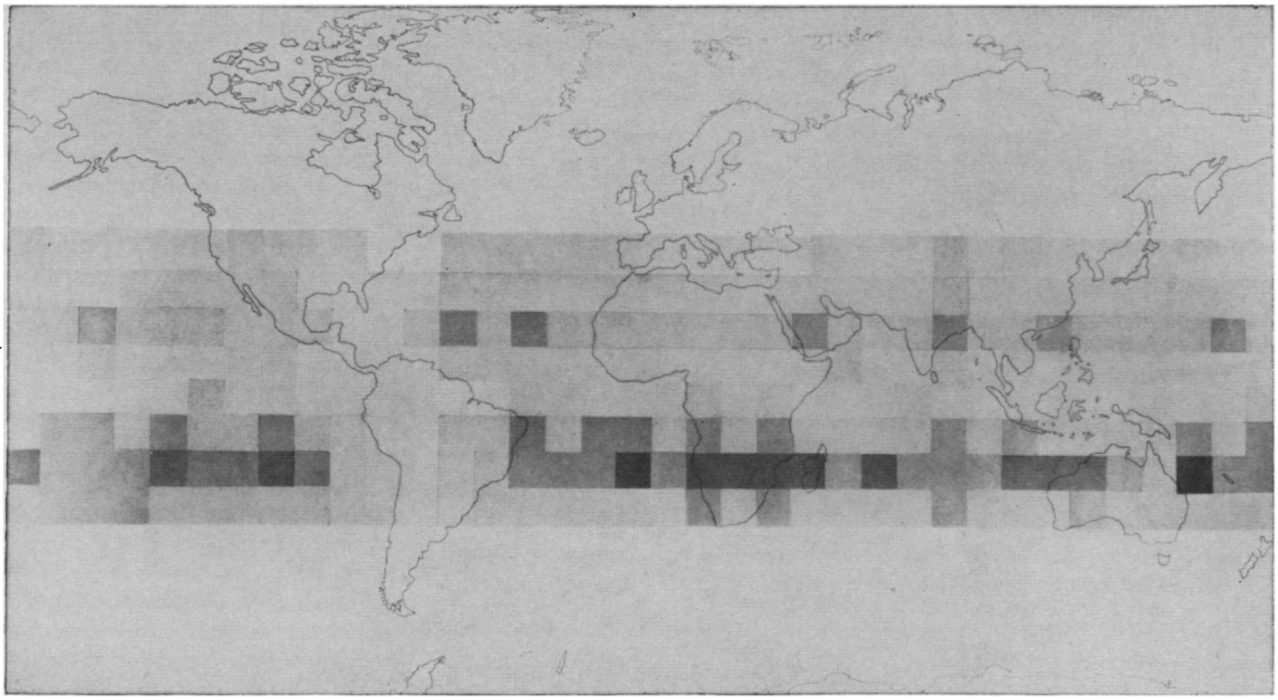

Fig. 1. Map divided into 10-deg squares shaded according to the period of time observed by photometers; the darkest shading indicates the longest period of observation. Satellite data transmission occurred in the vicinity of the American continents.

over the land to cloud cover over the sea. Arking (9) found from Tiros photographs that the percentage of cloud cover during the daytime over various land masses was essentially the same as that over water areas. It is interesting that the congregation of storms off the east coast of South America is essentially in the region of the geomagnetic anomaly. Whether the storms and the geomagnetic anomaly are indeed related must await confirmation, perhaps from an experiment similar to the one reported here aboard satellite OSO-F.

Some estimate can be made of the number of storm regions per unit time for the nighttime earth between the satellite observation limits of 35°N and 35°S. This figure must be a mean value for the period from February to October 1965. Furthermore, since from Fig. 2 the storm frequency over selected small areas can differ by more

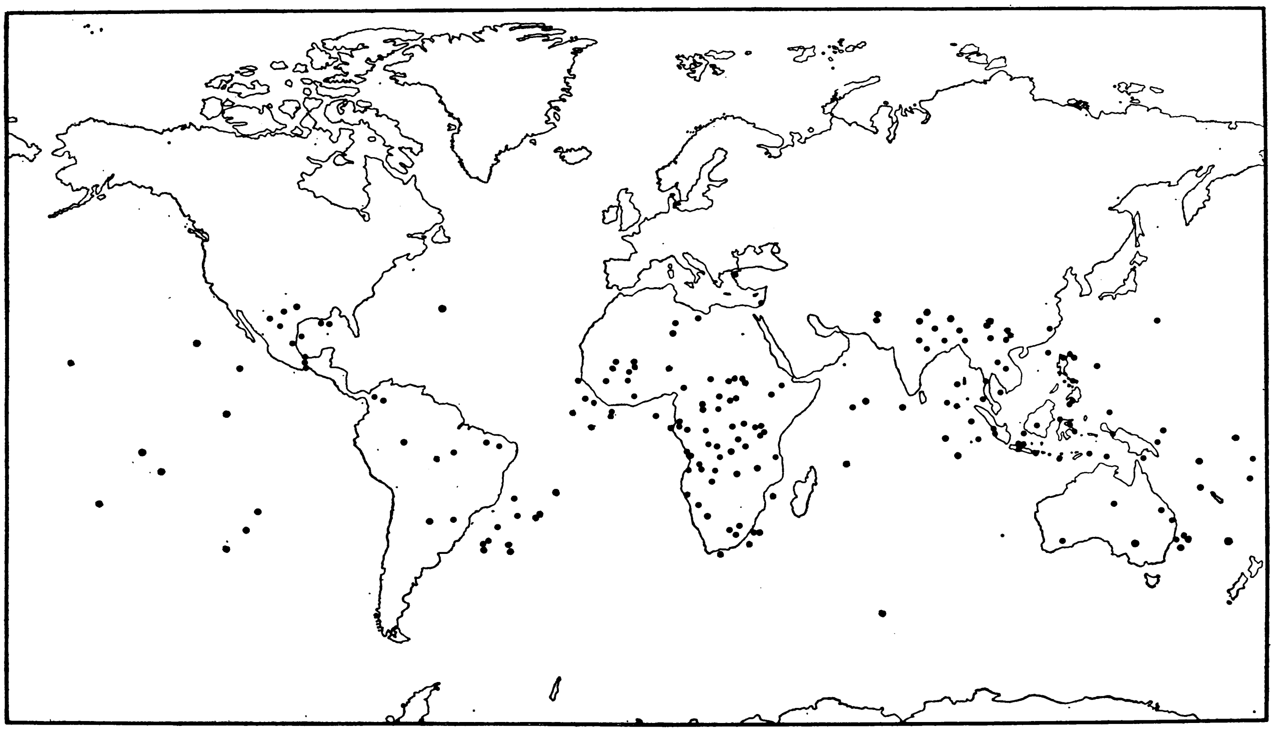

Fig. 2. Global distribution of lightning storms observed by the satellite photometers. The paucity of lightning storms over eastern South America is presumably due to the short sampling period shown in Fig. 1.

than an order of magnitude, a mean figure for the nighttime earth may be biased by the small sample and the degree of nonuniformity in Fig. 1.

About 200 storms (400 strokes) were detected in a time-area scan of 9500 deg^2 min. In other words, there appears to be one chance in 50 that in a given minute during the night there will be a thunderstorm complex in a 1-deg^2 area. Thunderstorm complexes are smaller than 1 deg^2 and in a given complex there are usually one or two electrically active cells producing an average of three flashes per minute (*1*). Brooks (*10*) as quoted by Humphreys (*11*), gives the average lifetime of a thunderstorm as about an hour. Thus the number of storms during the night between the above latitude limits is of the order of

$$\frac{25200 \text{ deg}^2 \times 720 \text{ min} \times 400 \text{ strokes}}{9500 \text{ deg}^2 \text{ min} \times 240 \text{ stroke/storm}} = \text{approx. } 3200$$

Although the storm frequency in general is higher during the day than during the night (*12*), the value obtained above is considerably lower than would have been expected from Brooks's figure of 44,000 storms per day. This discrepancy may be partly due to the threshold limit set for the satellite photometers and the difficulties of observing visual lightning output through the overlying cloud cover.

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Deep-Sea Tides 1250 Kilometers off Baja California

Abstract. *The tidal pressure fluctuations on the sea floor were read by a sensitive optical sensor that detects the rotations of a multiturn Bourdon helix. The record was analyzed in terms of the transfer functions between tidal elevations and gravitational driving. Off California, the semidiurnal tide attenuates considerably faster than the diurnal tide. Neither species satisfies the rate of decay expected from a Kelvin wave.*

Very little is known about tides over the expanse of the open ocean mainly because the traditional method of measuring tidal fluctuations along the coast—that is, referring the sea level to a stationary structure—is not applicable over the open ocean. However, tidal pressure fluctuations on the sea floor can be measured and, since they reflect the mass variation of the water column, are in a sense more fundamental than tidal elevations.

Detection of 0.5-cm changes of waterhead over a 5-km depth requires an instrumental stability and resolution of 10^{-6}. Limiting the drift due to plastic flow of the transducers requires sensitive strain detectors. Vibrating wire transducers furnish adequate sensitivity (*1*) provided that the recorded data are corrected for temperature effects. My data were obtained with an instrument equipped with a ferronickel Bourdon tube transducer that discriminates between pressure and temperature effects (*2*). The necessary sensitivity is obtained by optical readout (*3*). I have previously shown (*2*) that the instrumental drift can be fully explained by Andrade's beta creep (*4*) of the pressurized Bourdon helix. Thus, when we apply these well-understood principles, a high degree of drift rejection is achieved.

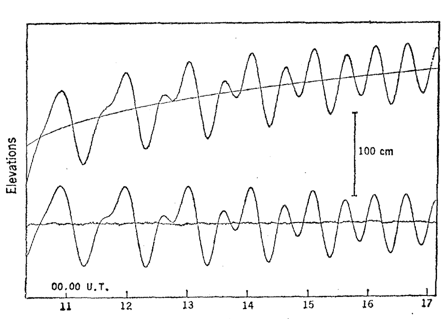

Fig. 1. The upper wavy line, slowly drifting upward, is a plot of the original data. The contribution of creep is superimposed on it, while the pure tidal and noise contributions are plotted below.

The observations were obtained during October 1968, 1150 km off Baja California, at a water depth of 4.4 km (24° 46.9′N, 129° 1.1′W). A plot of the original data is shown on Fig. 1 (upper wavy trace). Because of the extreme smoothness of the record, a simple least squares fit analysis with a series of harmonic functions permits resolution of many constituents in each species, a result not possible with equivalently short coastal records. We have also separated the diurnal constituents K_1 and P_1 and the semidiurnal constituents S_2 and K_2, taking into consideration their equilibrium amplitudes and phrases (see Table 1).

A more realistic method by which contamination of the resolved constituents by the unresolved ones can be avoided consists of estimating the transfer functions between gravitational forces and tidal response. Such an analysis has been carried out by a least squares fit technique in which the diurnal and semidiurnal transfer functions are computed separately to best advantage. The transfer functions are expanded in frequency-dependent Taylor series around the center of each tidal band. This yields a system of linear equations from which the coefficients of the successive terms are obtained. Analysis of the residual noise by a Fourier technique indicates how many terms in the Taylor expansion are required to bring the residual energy density in the tidal band below the adjacent level. With the record shown this result is achieved with the first two terms (Table 1). The Fourier spectra of the residual noise are shown for the harmonic method (Fig. 2a) and for the transfer function method with one and two terms (Fig. 2, b and c).

The errors in the calculated transfer functions are estimated by varying their parameters until the dips in the Fourier spectrum (Fig. 2c) at diurnal and semidiurnal frequencies disappear. When nongravitational and cusps energies (*5*)