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SUMMARY AND DISCUSSION

In this final chapter are summarised the important points emerging out of the studies on the lunar tidal oscillations in (a) the critical frequency of the $F_2$ layer of the ionosphere and the height of maximum electron density over Ahmedabad, and (b) the critical frequency of the $F_2$ layer of the ionosphere over Panama, Huancayo and Buenos Aires. This is followed by a comparison with the results obtained by other workers and a short discussion.

(a) Lunar tidal variations in $f_{o}F_2$ and $h_pF_2$

The maximum annual average amplitude of the lunar tide in $f_{o}F_2$ during March 1953 to February 1956 was 0.34 Mc/s. This occurred at about 12 solar hour and the corresponding lunar phase was 11.7 lunar hour. The maximum yearly amplitude of the tide in $h_pF_2$ was 4.2 Km occurring at about 12 solar hour with its phase at about 8.3 lunar hour.

The variation of the amplitude and phase of the tide in $f_{o}F_2$ with solar time was studied separately for each season. During the equinoxes, a maximum amplitude
of 0.50 Mc/s occurred at about 12 solar hour with its phase at about 0.90 lunar hour; in winter (December solstice) also, the maximum amplitude of 0.51 Mc/s was observed at about 12 solar hour with its phase at 10.0 lunar hour. During summer (June solstice), however, the maximum amplitude of 0.32 Mc/s occurred at about 15 solar hour and its phase at 11.7 lunar hour. On harmonic dials the vectors representing the amplitude and phase always rotated in the anti-clockwise direction.

Seasonally, the maximum amplitude of the lunar tide in $f_0F_2$ averaged over all solar hours, occurred during the equinoxes with a magnitude of 0.14 Mc/s and phase 2.2 lunar hour. The average lunar tide in $h_pF_2$ had its amplitude of about 1.23 Km with its phase at 7.3 lunar hour.

(b) Lunar variations in $f_0F_2$ over Panama, Huancayo and Buenos Aires

The variation with solar time of the semi-diurnal lunar tide in $f_0F_2$ was studied for each season separately and also annually. Broadly, the amplitude of the tide was maximum during the December solstice and equinoxes at all the three places and negligibly small and random in phase during the June solstice. The maximum annual average tides which occurred at Panama, Huancayo and Buenos Aires respectively were 0.35 Mc/s (3.9 %) at 12 hour, 0.37 Mc/s (4.6 %) at 11 hour and 0.43 Mc/s (5.0 %) at 16 hour. Their
respective phases were 11.3, 4.6 and 7 to 8 lunar hours. The vectors representing the amplitude and phase of the semi-diurnal lunar tide rotated in the anti-clockwise direction at all the three stations. There was a definite indication of enhanced tidal amplitudes at 05 solar hour at Panama and Huancayo. At Buenos Aires, however, the tidal effect at 05 hour was smaller.

Seasonally, the maximum amplitudes of the semi-diurnal tide in $f_0F_2$ happened in one of the months of the winter solstice or the equinoxes. Generally, larger tidal amplitudes were observed around 12 solar hour than those around 00, 06 and 18 hours for Panama and Huancayo. In the case of Buenos Aires, however, the amplitudes around 18 hour also were significantly large for all the months.

As for the diurnal component of the lunar tide, its amplitude at all the stations was larger during the equinoxes than during the two solstices. Their phases during the June solstice were the most random.

Discussion

Many workers have found an enhancement of lunar tidal perturbation in the $F_2$ layer of the ionosphere during daytime near the magnetic equator. Martyn (1947) showed that the phase and amplitude of the semi-diurnal lunar variations in $f_0F_2$ and $h_mF_2$ at Huancayo were markedly dependent on solar
McNish and Gautier (1949) analysed $f_0F_2$ data for a number of low latitude stations and concluded that $f_0F_2$ lunar tide at solar noon had large maxima about two days after each lunar quarter at stations near the magnetic equator. Burkard (1951) found that the amplitude of lunar tide calculated from daytime $f_0F_2$ was much larger than that calculated from all day $f_0F_2$; and also that the night-time $f_0F_2$ at Huancayo did not show any lunar tidal variation. Brown (1956) analysed $F_2$ layer data for another equatorial station, viz. Ibadan. He also reported large luni-solar variations in $F_2$ layer parameters. He found large seasonal variations of their amplitude and phase, the latter changing considerably during the course of a solar day. All these and other similar results led to the conclusion that the large lunar $F_2$ variations in the magnetic equatorial zone occur only during daylight hours.

In other words, luni-solar tide is predominant in this zone. According to Martyn, the vertical drift motions of charged particles caused by their horizontal movements across the horizontal lines of the magnetic field of the earth, in the presence of an electric field, are responsible for the large lunar tidal variations in the $F_2$ layer near the magnetic equator.

It is interesting to note that for all the stations considered here, viz. Ahmedabad, Panama, Huancayo and Buenos Aires, the amplitudes of lunar tide in $f_0F_2$ were much larger
during the December solstice than during the June solstice. Similar results were obtained by Bartels (1950) at Huancayo. He concluded that the amplitude of daytime $f_0F_2$ lunar tide at Huancayo in local summer was about five times larger than in local winter. The ratio of the amplitude of the magnetic lunar variation in summer to that in winter was about three at Huancayo. The phase of the lunar tidal variations in $f_0F_2$ at the places examined, namely Panama, Huancayo and Buenos Aires, was very random during the June solstice. Again, the rotation of the vector representing the amplitude and phase of lunar tide was essentially in the anti-clockwise direction for all the four stations.

Rastogi (1963) presented a qualitative general picture of the variation of the lunar tide in $f_0F_2$ at Panama, Huancayo and Buenos Aires. He found that the maximum lunar perturbation in $f_0F_2$ was felt at Huancayo at the time of the midday bite-out of $f_0F_2$, while at Panama and Buenos Aires it was observed at the time of the afternoon peak of $f_0F_2$. This point was verified quantitatively by our detailed analyses.

The maximum yearly average amplitude of the lunar tide in $f_0F_2$ at Panama (a northern tropical latitude station), at Huancayo (a magnetic equatorial station) and at Buenos Aires (a southern tropical latitude station) occurred at 12, 11 and 16 solar hours respectively. Now the corresponding $f_0F_2$ maxima at Panama and Buenos Aires occurred at about 15 solar hour, and
the maximum bite-out of $f_{0F_2}$ at Huancayo happened at about 12 hour. Thus, the maximum lunar tidal amplitudes at Huancayo and Buenos Aires occurred almost simultaneously with the afternoon bite-out of $f_{0F_2}$ and the maximum of $f_{0F_2}$ respectively. It remains to be seen whether the large lunar perturbations in $f_{0F_2}$ observed at tropical latitude stations are due to the processes which are responsible for higher values of $f_{0F_2}$ at those places.

At Panama and Huancayo large amplitudes of lunar tides in $f_{0F_2}$ were also observed at 05 hour. A similar result was reported by Martyn (1947) at Huancayo. He found that the half-amplitude of the density variations in $N_{\text{max}}$ had a value of 14.6 % at 05 hour while it was only 2 % at 07 hour. It is difficult to understand why Buenos Aires shows reduced tidal effect around 05 hour, even though the values of $f_{0F_2}$ at all the three stations at that time are very low.

Thus, whereas Panama behaves as a tropical latitude station, with the half-amplitude of $f_{0F_2}$ lunar tide of about 0.35 Me/s (3.9 %) at 12 hour and its phase at 11.3 lunar hour, Buenos Aires shows very different lunar tidal variations with a semi-diurnal amplitude of 0.43 Me/s (5.0 %) at 16 hour and its phase between 7 to 8 lunar hours.

At some southern high latitude stations, Rastogi (1960) had observed abnormal features of the $F_2$ region of the ionosphere.
For example, in the west zone (American zone) the ionization in the F2 region of the ionosphere at a station in the southern hemisphere was lower than that at a station of equal magnetic dip in the northern hemisphere. There was no such difference in the east zone. Again, during mid-night hours of local summer months abnormally high values of $f_0F_2$ were observed at the southern stations in the west zone.

Whether the anomalous behaviour of the lunar tide in $f_0F_2$ is connected with the anomalous behaviour of $f_0F_2$ itself and how far either of these is connected with the asymmetry of the geomagnetic field in the southern hemisphere are matters requiring further study.