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HF Doppler Observations during the Total Solar Eclipse of 16 February 1980

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HF Doppler observations were made at Waltair on 10 MHz ATA standard time and frequency CW signal from New Delhi during the total solar eclipse of 16 Feb. 1980 across South India. The Doppler record showed characteristic frequency variations particularly observable on an eclipse day, which throw some light on reflection height changes in the ionosphere during an eclipse. The record also exhibits a quasi-periodic structure of 6-min period which would not be present normally for this time of the day. This feature could be an eclipse generated phenomenon.

1. Introduction

The HF Doppler technique originally developed by Watts and Davies[1] has proved to be a potential experimental method for studies of disturbances in the E- and F-regions of the ionosphere. As this technique is particularly sensitive to the time-rate changes in the electron density, several attempts have been made to study the effect of solar eclipse on the upper atmosphere on various occasions using this method.[2-5] This method has been very useful to investigate one of the important aspects of the eclipse, viz. the eclipse generated atmospheric gravity wave phenomenon in the upper atmosphere.

Chimonas and Hines[6] and Chimonas[7] have suggested that during a solar eclipse the lunar shadow moves at a supersonic velocity through the earth's atmosphere causing reduction in thermal input at various levels in the atmosphere. This would give rise to the generation of atmospheric gravity waves in the wake of the shadow region which could effectively be detected at distances far away from the eclipse path. To check the validity of this hypothesis experimentally, several attempts have been made mainly during the eclipses of 7 Mar. 1970 (United States),[2,8-12] 30 June 1973 (South Africa)[3,13-15] and 23 Oct. 1976 (Australia),[5,16-19] the annular solar eclipse of 19 Apr. 1958 in Japan[4] and the partial eclipse of 29 Apr. 1976 at Trivandrum.[20]

After a careful study of literature, it can be observed that despite the rigorous experimental efforts put up in detecting the wave phenomenon during the various eclipses since 1970, no definite conclusion has been arrived at so far either in favour or against the hypothesis of Chimonas and Hines.[6] This is partly due to the disturbed magnetic conditions which existed on eclipse days.

In the present paper we present the HF Doppler observations made at Waltair during the total solar eclipse of 16 Feb. 1980 over South India.

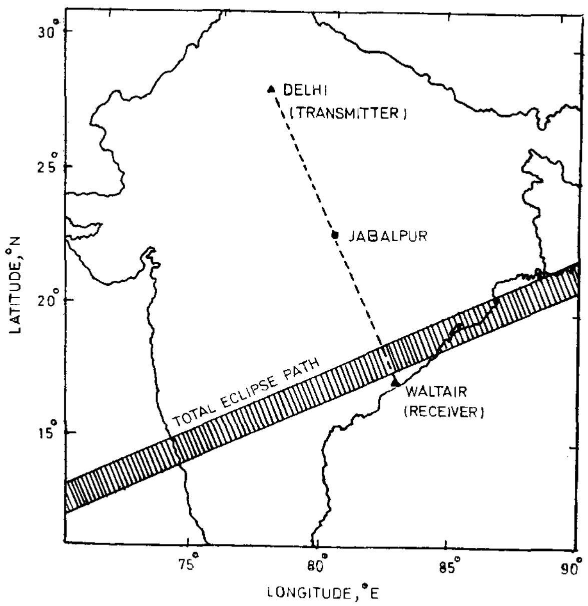

Fig. 1—Map showing the locations of the transmitter, receiver and the approximate reflection point and a rough sketch of the totality path of the total solar eclipse of 16 Feb. 1980

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2. Experimental Details

An HF Doppler system has been set up at Waltair (17° 43'N; 83°18'E) to monitor the Doppler frequency changes of 10 MHz ATA standard time and frequency signal transmitted from Greater Kailash, New Delhi (28° 33·6'N; 77° 18·8'E) under the auspices of the National Physical Laboratory, New Delhi. The system is similar to that described by Watts and Davies.[1] The received 10 MHz signal via ionosphere is compared with a highly stable local oscillator frequency of the same value received with a few Hertz negatively offset. The beat frequency is recorded on a pen-chart. The signal is received over an oblique path, the reflection point for one-hop mode being approximately located over Jabalpur (23°N; 80°E). The location of the transmitter, receiver and a rough sketch of the totality path across South India are shown in Fig. 1. The eclipse details at the reflection point are as follows.

Distance from the totality path ~650 km	
First contact	1435 hrs IST (0905 hrs UT)
Maximum	1550 hrs IST (1020 hrs UT)
Last contact	1656·5 hrs IST (1126·5 hrs UT)
Magnitude at maximum	0·849
Obscuration	0·817

3. Results and Discussion

The Doppler record of 16 Feb. 1980 is shown in Fig. 2. For comparison, the Doppler record of the control day, viz. 17 Feb. 1980, is shown in Fig. 3. At the time of the first contact at 1435 hrs IST the signal strength has become very low and no useful Doppler record has been obtained around this time. In the signal amplitude simultaneously recorded, there is an indication of signal fade-out around this time. At around 1442 hrs the signal strength has reached a level enough to give a useful Doppler record. The record shows a negative shift from the normal zero level which continues up to the time of maximum obscuration. As the Doppler technique is particularly sensitive to the changes in the reflection level, the observed negative trend could be mainly due to the upward motion of the reflection level and the effect of recombination processes in the lower ionosphere between the first and the third contacts on the Doppler record can be neglected.[21] The Doppler shift shows a large negative gradient around 1554 hrs. Thereafter, the record exhibits a reversal and a gradual positive gradient indicating the retardation of the upward motion of the reflection level and a subsequent downward movement. This gradient is about 0·2 Hz per min. It crosses the zero level corresponding to the normal reflection level at about 1605 hrs and attains a maximum Doppler shift of as large as 0·8 Hz at about 1630 hrs. This positive gradient in the Doppler record indicates gradual build-up of electron production started after the third contact. After 1630 hrs the record has shown a negative gradient (in the positive side of the

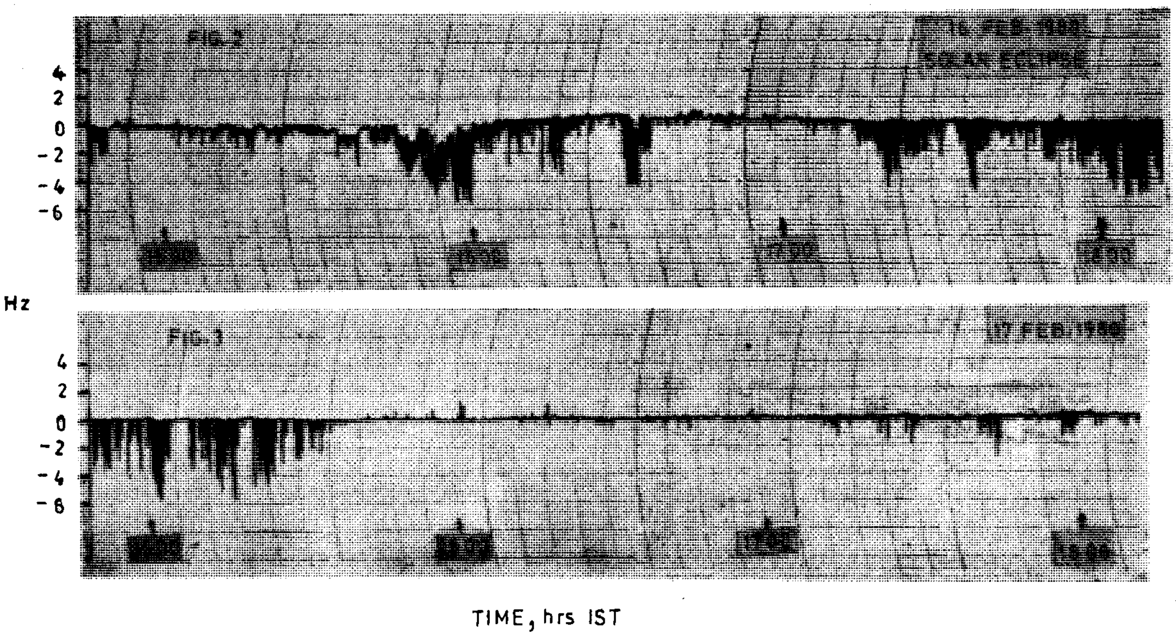

Fig. 2—Dopplometer record of 16 Feb. 1980
Fig. 3—Dopplometer record of 17 Feb. 1980

Doppler record) which settles down to zero level at around 1724 hrs. The instability of the Doppler trace after 1720 hrs might have been due to the presence of small-scale irregularities near the reflection height.

Another feature of importance of the eclipse day Doppler record is the wavelike acitivity in the Doppler frequency changes. The disturbance on the Doppler record seems to have existed right from the beginning of the eclipse. A small quasi-periodic structure with not much significant amplitude can be observed between 1512 and 1524 hrs. However, the wave structure appears with pronounced activity around the maximum phase of the eclipse. The wave amplitude is largely amplified during this phase and a periodicity of about 6 min can be clearly seen between 1542 and 1606 hrs. It is interesting to note that in the measurements of the angle of arrival in the totality path of the eclipse on 23 Oct. 1976 eclipse, Baulch and Butcher[16] detected a wavelike variation of about the same period as observed by the present technique. However, in our case the reflection point is about 650 km away from the eclipse path. Sears[2] reported a period of 25 min in his HF Doppler measurements during the 7 Mar. 1970 eclipse; but his results were not unambiguous. Broche and Crochet[3] reported a periodicity of 10 min in their HF Doppler observations during the 30 June 1973 eclipse. Ichinose and Ogawa[4] analyzed the HF Doppler data of 19 Apr. 1958 annular solar eclipse in Japan and found a gravity wave of period 22 min during the eclipse time. The characteristic frequency variations observed by the present technique are similar to those obtained by Cornelius and Essex[5] during 23 Oct. 1976 eclipse; but they reported no wave activity attributable to the eclipse. But in the present results, the difference between the eclipse day Doppler record and the record of the next day can be clearly seen. As mentioned earlier, there is an apparent wave activity on the eclipse record.

As in the case of many previous solar eclipses this time also there is a strong magnetic activity on the eclipse day. The magnetic storms can also generate atmospheric gravity waves in the upper atmosphere and it is not possible to establish a direct and unambiguous cause and effect coordination between the solar eclipse and the observed quasi-periodic Doppler frequency fluctuation. But this can be verified indirectly by way of checking whether the observations taken by the present technique are prone to be affected by geomagnetic variations, and if so, under what type of magnetic conditions the

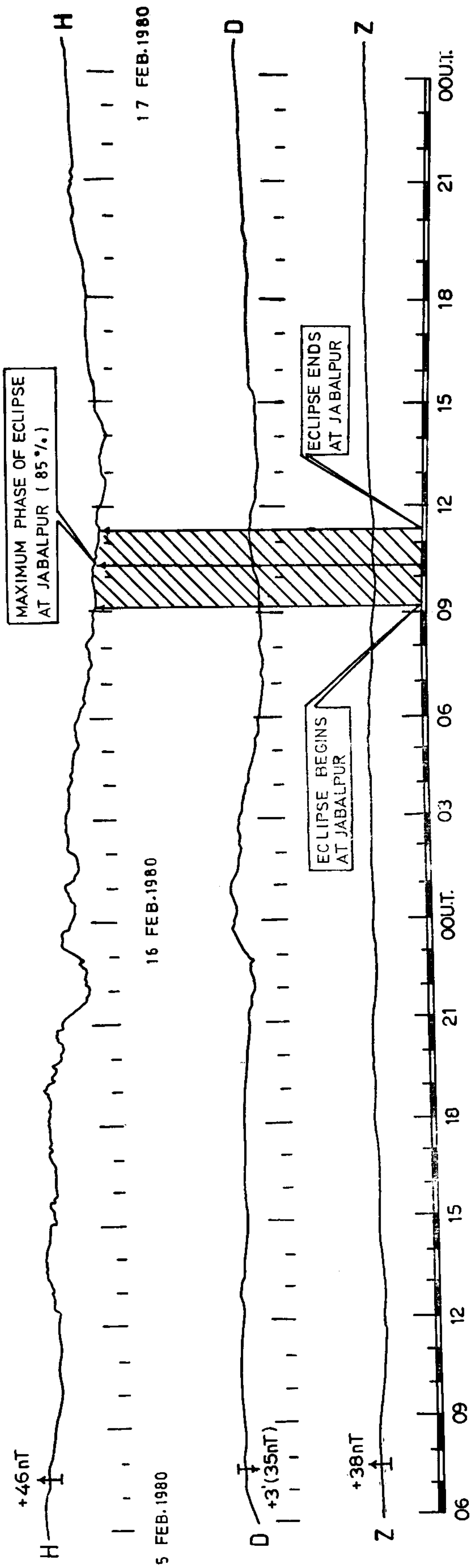

Fig. 4—Magnetogram at Hyderabad (17° 26′N; 78° 27′E) showing the three components of the geomagnetic field before, during and after the eclipse period

effect would be observable. Davies[22] reported simultaneous observation of a rapid increase in frequency with the onset of magnetic storm. Agy *et al.*[23] observed remarkable similarity between Doppler frequency fluctuations and variations in the D-component of the geomagnetic field. These observations led to the studies of Jacobs and Watanabe[24] and Lewis[25] and the latter concluded that the overall coincidence between geomagnetic variations and Doppler frequency fluctuations was poor despite the fact that certain isolated events like sudden impulses, SSCs and Pi-2 micropulsations would accompany sudden frequency changes, the converse being not true. Hence to find out whether there are such rapid changes in the geomagnetic field during the time of the eclipse, the magnetograms at a nearby magnetic observatory at Hyderabad (totality 99·4%) have been referred (Fig. 4). An SSC can be seen in the *H*-component commenced on 15 February at 1235 hrs UT with an amplitude of 8γ. The storm ended on 16 February at 2300 hrs UT and yielded a range of 152 γ in *H* at this station. However, except for small fluctuations in the *H*-component there were no rapid variations in the three components during the eclipse period (0905-1126 hrs UT). The small variations in the *H*-component do not seem to cause a Doppler frequency fluctuation of as large as has been observed on the eclipse day Doppler record. This leads to the conclusion that the chances that the magnetic conditions which existed on 16 February, to cause the observed periodic fluctuations in the Doppler record are remote and that this is most probably an eclipse generated phenomenon.

4. Conclusion

The quasi-periodic structure of 6-min period observed on the eclipse day Doppler record around the maximum phase of the eclipse between 1542 and 1606 hrs indicates the generation of atmospheric gravity waves due to the passage of moon's shadow in the earth's atmosphere at supersonic speed as predicted by Chimonas and Hines.[6] However, this periodic structure does not exist for a considerable time, probably because, as the eclipse path across South India is almost linear, no focusing could be expected at such a relatively short distance of 650 km from the eclipse path (as in our case). Also, the claim that the observed phenomena is eclipse-generated seems to be valid without being affected by the presence of strong magnetic activity which existed on the eclipse day.

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References

1. Watts J M & Davies K, *J geophys. Res.*, 65 (1960), 2295.
2. Sears R D, *J. atmos. terr. Phys.*, 34 (1972), 727.
3. Broche P & Crochet M, *J. atmos. terr. Phys.*, 37 (1975), 1371.
4. Ichinose Takumi & Ogawa Toru, *J. geophys. Res.*, 81 (1976), 2401.
5. Cornelius D W & Essex E A, *J. atmos. terr. Phys.*, 40 (1978), 497.
6. Chimonas G & Hines C O, *J. geophys. Res.*, 75 (1970), 875.
7. Chimonas G, *J. geophys. Res.*, 75 (1970), 5545.
8. Davis M J & da Rosa A V, *Nature, Lond.*, 226 (1970), 1123.
9. Carlson H C, Harper R, Wickwar V, Showen R L, Behnke R, Trost T F, Cogger L R & Nelson C J, *Nature, Lond.*, 226, (1970), 1124.
10. Arendt P R, *J. atmos. terr. Phys.*, 34 (1972), 719.
11. Lerfald G M, Jurgens R B, Vesecky J & Washburn T W, *J. atmos. terr. Phys.*, 34 (1972), 733.
12. Butcher E C, *J. geophys. Res.*, 78 (1973), 7563.
13. Schodel J P, Klostermayer J & Rottger J, *Nature, Lond.*, 245 (1973), 87.
14. Hunter A N, Holamar B K, Feldgate D G & Kellehar R, *Nature, Lond.*, 250 (1975), 205.
15. Bertin F, Hughes K A & Kersley L, *J. atmos. terr. Phys.*, 39 (1977), 457.
16. Baulch R N E & Butcher E C, *Nature, Lond.*, 269 (1977), 497.
17. Hajkowicz L A, *Nature, Lond.*, 266 (1977), 147.
18. Morton F W & Essex E A, *J. atmos. terr. Phys.*, 40 (1978), 111.
19. Butcher E C, Downing A M & Kole K D, *J. atmos. terr. Phys.*, 41 (1979), 439.
20. Vaidyanathan S, Reddi C R & Krishna Murthy B V, *Nature, Lond.*, 271 (1978), 40.
21. Robinson I & Dyson P L, *J. atmos. terr. Phys.*, 37 (1975), 1459.
22. Davies K, *Nature, Lond.*, 193 (1962), 763.
23. Agy V, Baker D M & Jones R M, *NBS tech. note No.* 306, 1965.
24. Jacobs J A & Watanabe T, *Radio Sci.*, 1 (1966), 257.
25. Lewis T, *Can. J. Phys.*, 45 (1967), 1549.