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Anomalous Seasonal Variation of Radio Waves in the VLF, LF, MF & HF Bands in relation to Middle Atmospheric Phenomena

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Seasonal variations of radio waves in the VLF, LF, MF and HF bands have been critically examined. Observations in the tropical region Calcutta indicate an anomalous additional maximum in signal strength of radio waves in summer with a prominent minimum in October. Examination of the data reveals that the anomaly may be related to the diffusion of hydrated cluster of positive ions $H^+ (H_2O)_n$ from the lower atmosphere to the lower ionospheric heights.

1. Introduction

The seasonal variation of the ionospheric propagation characteristics has been extensively studied in different countries.[1-10] Most of the results in the LF, MF and HF bands indicate that the absorption of the signal is more in summer than in winter. At VLF, however, the seasonal variation exhibits an opposite trend. Recent observations in the tropical regions indicate an anomalous additional maximum in summer often with a prominent minimum in October. In this paper, an examination of the data obtained in Calcutta as well as in other tropical regions is made for the study of this anomaly.

2. Observations

Fig. 1 shows the seasonal variation of reflection coefficient at VLF and LF bands for different propagation distances in temperate latitudes.[1] Fig. 1 shows a maximum in winter and minimum in the summer. The number within parentheses indicate effective frequencies in kHz. Fig. 2 shows the variation of long wave reflection coefficient with effective frequency for different seasons in the solar maximum and minimum years.[1] Fig. 2 also shows the general trend that the reflection coefficient decreases with frequency, the dependence being most marked in a summer day and least at night. Also, for a given frequency the daytime reflection coefficient is more in winter than in summer. Fig. 3 shows the seasonal variation of the absorption measured at vertical incidence on 150 kHz in Pennsylvania State University.[11-15] Fig. 4 also shows that absorption is maximum in summer and minimum in winter, and is in conformity with the reflection coefficient results of Belrose.[1]

Fig. 4 shows the amplitude of VLF and LF signals measured at another temperate latitude station.[2] Here we see that the noontime amplitudes for 16 kHz and 60 kHz remarkably exhibit the usual seasonal trend with a maximum in winter and minimum in summer. However, the results for the midnight value at 16 kHz as well as the noontime values at 2·61 MHz do not indicate any discernible seasonal dependence. Fig. 5 depicts the amplitudes of the fields at 164 kHz for the Tashkent-Delhi path measured at All India Radio, Delhi.[3] It is noticed from Fig. 5 that the seasonal variation is very small, the summer and winter values being nearly the same. In Fig. 5(a) the dotted line

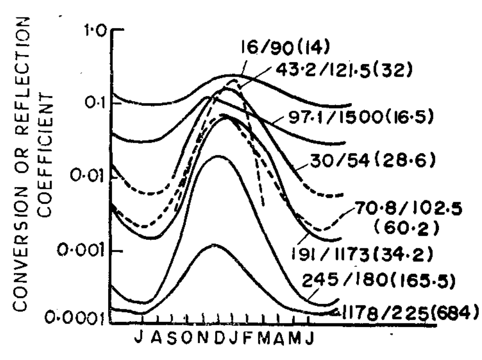

Fig. 1—Curves showing the seasonal variation of reflection coefficients with effective frequency for different seasons [The notation marked on the curves, e.g. 245/180 (165·5) means a wave of frequency of 245 kHz transmitted to a distance of 180 km with an effective frequency ($f \cos i$) of 165·5]

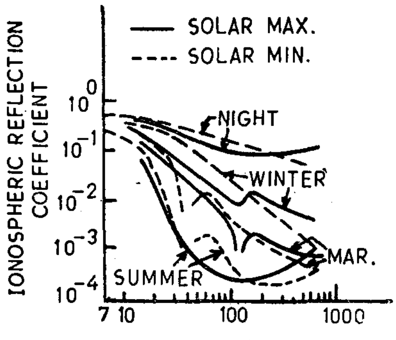

Fig. 2—Curves showing the variation of long wave reflection coefficient with effective frequency for different seasons

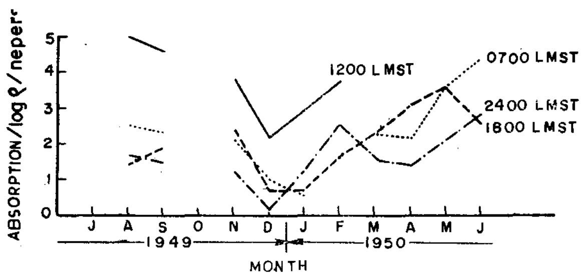

Fig. 3—Plots showing the seasonal variation of absorption measured at vertical incidence on 150 kHz in Pennsylvania State University

indicates the CCIR value, which shows a minimum in summer and maximum in winter. The measured field thus seems to be significantly greater in summer than that predicted in CCIR curve. Also in Fig. 5(b) the CCIR values indicated by double dots are much lower than the measured values.

Fig. 6 shows some anomalous behaviour of the seasonal variations measured at a temperate latitude station.[1] Fig. 6(a) shows an opposite type of seasonal dependence of field strength with the maximum in summer and minimum in winter measured at 70·384 kHz for a distance of 1637 km. In Fig. 6(b) we notice an interesting anomaly for the nighttime conversion coefficient as indicated by full line. Here we notice a double maximum one being in winter and other being in summer.

Fig. 7 shows the seasonal variation of field strength of radio waves in the LF, MF and HF bands as observed at Calcutta. The LF signal is a radio navigational signal at 280 kHz from Jessore (lat., 23°10′ N ; long., 89°10′ E) in Bangladesh and China Bay (lat., 9°11′ N ; long., 81°11′ E) in Ceylon respectively. The respective distances of the transmitting stations being about 110 km and 1800 km from the receiving station Calcutta

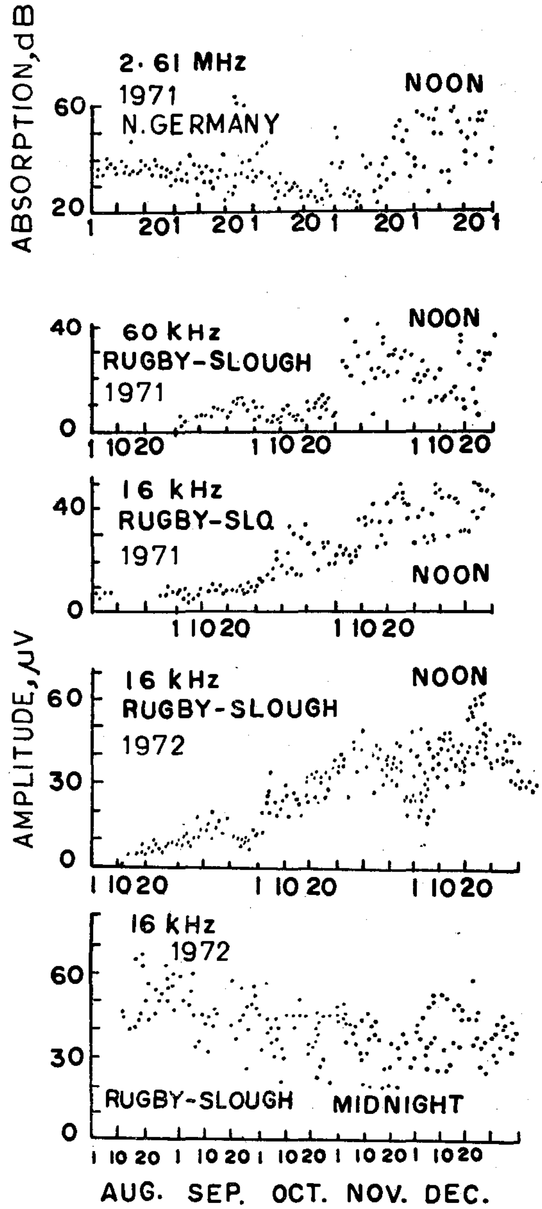

Fig. 4—Variations of the absorption near noon of 2·61 MHz waves transmitted over a path of 295 km in Northern Germany (top) and of the amplitudes near noon and midnight of the abnormal components of 60 and 16 kHz waves transmitted from Rugby to Slough during August-December

(lat., 22° 34′ N ; long., 88° 24′ E). The station, Jessore operating on 280 kHz in the morning goes off the air in the evening when the station, China Bay, operating on the same frequency (280 kHz) starts and continues throughout the night. The MF signal is due to the local Vividh Bharati broadcast at 1320 kHz at a distance of about 54 km from the receiving location. The HF signal is due to the radio broadcast signal at 17·825 MHz from Frunze (lat., 42° 59′ N ; long., 74° 0′ E) at a distance of about 2650 km from Calcutta. In Fig. 7 signal strength at LF shows a maximum both in summer and winter, the summer maximum being more pronounced than the winter maximum. A similar tendency is exhibited also in the MF and HF bands. Such double maxima have also been observed at Ahmedabad as reported by Kotadia *et al.*[16]

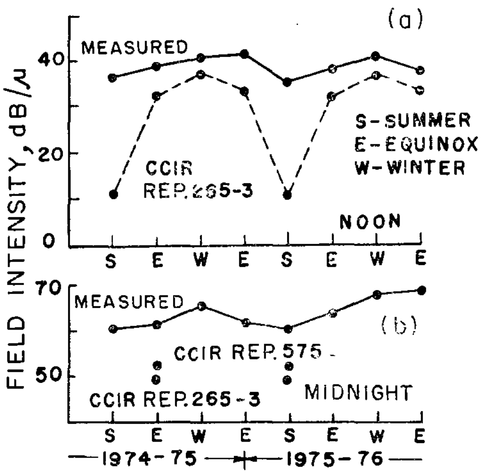

Fig. 5—Plots showing the seasonal variation of median values of field intensity (dB/V) at 164 kHz for the Tashkent-Delhi path : (a) noon value and (b) midnight value

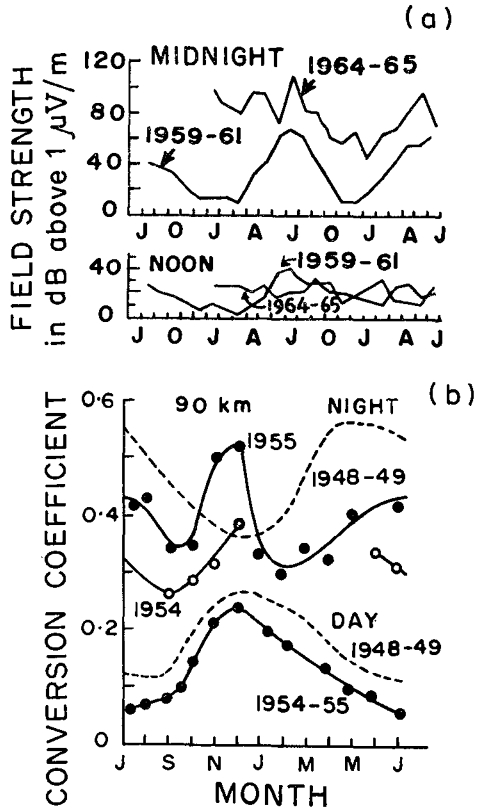

Fig. 6—Anomalous seasonal variation of (a) field intensity of 70·384 kHz signal for a distance of 1637 km from Comfort Cove to Ottawa ; and (b) conversion coefficient at 16 kHz for a distance of 90 km from Rugby to Cambridge

3. Discussion

The usual trend of the signal strength variation with a single maximum occurring in winter is expected from the solar zenith angle dependence of the effective ionizing flux affecting the ionization of the LF absorption levels.[17] The appearance of the secondary peak in summer as observed in Fig. 7 suggests the influence of another agency taking control at such times. The agency may be the hydrated ion clusters which is now known to affect the electron density in the D-region.[18–21] The mesospheric minor constituents other than NO, in fact, also play an important role in the ionization process of the D-region.[22] Such constituents include O, O_3, H_2O and CO_2. The H_2O molecules in the form of water vapour are dissociated at a height above 70 km and a large part of the atomic hydrogen produced escapes from the atmosphere and there is a continuous transport of water vapour through the stratosphere and mesosphere.[21] The water vapour causes hydration of ions in the D-region. In fact, below about 82 km the water cluster ions $[H^+ . (H_2O)_n]$ dominate both during day and night. The ions, $H_3O^+ . H_2O$, are apparently the major components of cluster ions. The hydrated ions lead to a net loss of electrons due to the very large dissociative recombination coefficient (10^{-5} cm^{-3} sec^{-1}) involved.[18,19] This is strikingly demonstrated by a sharp ledge of [20,22,23] elctron density around 82 km height above which the cluster ions suddenly start disappearing while the electron density starts rising rapidly (Fig. 8). Fig. 9 shows a typical height distribution of hydrated ion clusters at midlatitudes during midday. It is seen that the concentration is

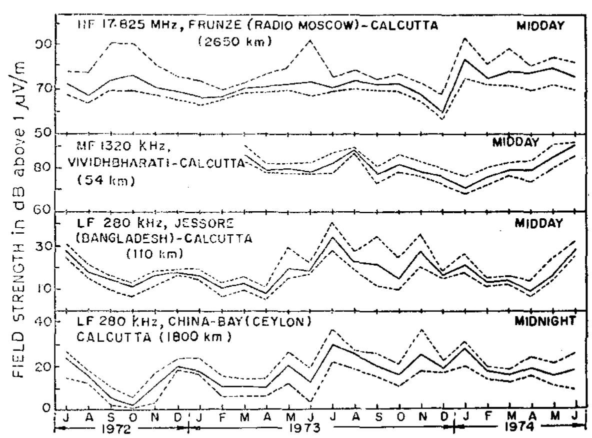

Fig. 7—Curves showing seasonal variation of field strength of radio waves in the LF (280 kHz), MF (1320 kHz) and HF (17·825 MHz) bands as observed at Calcutta

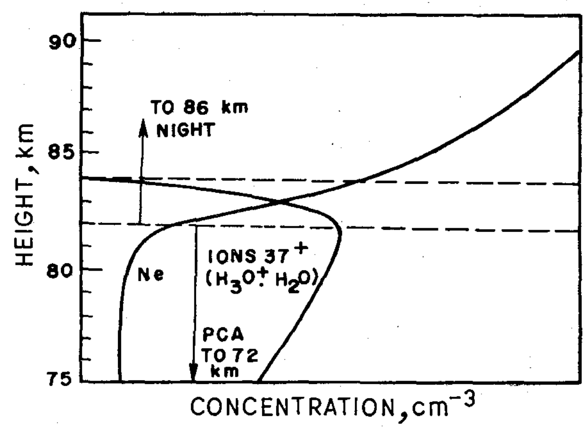

Fig. 8—Curves showing the ledge in electron density and level of disappearance of water cluster ions in the mesosphere

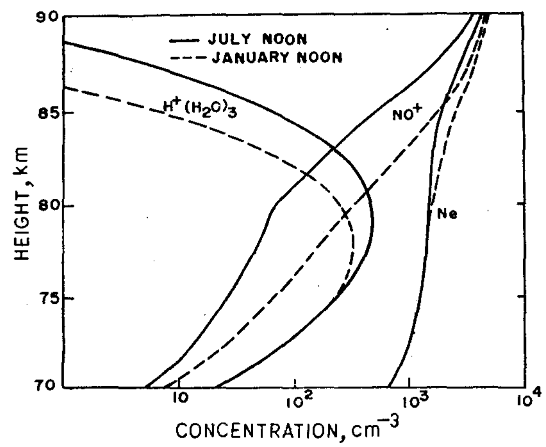

Fig. 9—Plots showing the computed height distributions for certain positive ions and for electrons with mid-latitude D-region for summer (July) and winter (January) months

maximum in the height range 75-85 km. Fig. 9 also indicates a seasonal trend with the concentration of the cluster ions being more in the summer month, July, than in the winter month, January.[23] Such a seasonal trend is likely to be more prominent in tropical regions where the water vapour content is significantly higher.

Fig. 10(a) shows the variation of microwave attenuation in X-band measured at National Physical Laboratory, New Delhi.[24] The absorption is proportional to the integrated water vapour of the atmosphere. Thus, we see from Fig. 10(a) that the water vapour content is significantly more in summer than in winter. The supply of such water vapour from surface level to the mesospheric or stratospheric height would be abundant in tropical regions during the summer months. Fig. 10(b) illustrates this point. The curves indicating that the evapo-transpiration potential is maximum in summer and minimum in winter.[25] It appears that

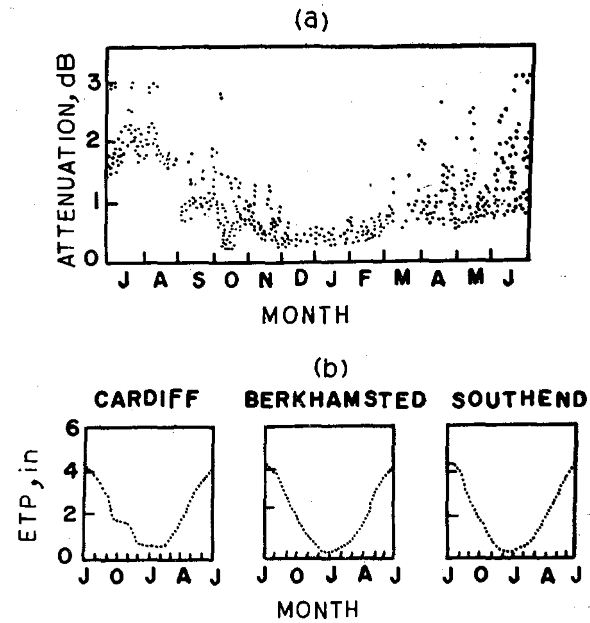

Fig. 10—(a) Seasonal variation of water vapour in the atmosphere observed at 22·235 MHz by microwave radiometer at National Physical Laboratory, New Delhi; and (b) the average annual evapo-transpiration potential (ETP) for stations in western, central and eastern Britain

the loss of electrons from the absorption level of the LF signals due to the dominance of the hydrated ions in the summer months may explain the second maximum of signal strength in summer. The water vapour content at lower atmospheric levels and water vapour density near surface are, in fact, highly correlated. This is also borne out by a recent work of Aro[26] who found that the correlation is more than 0·93 and the water vapour content as well as the water vapour density is maximum in summer and minimum in winter. In support of our observations reference may also be made to a recent work by Fedynsky and Ushkov[27] who found that the water vapour content between heights 30 and 80 km is maximum in July-August and minimum in February-March.

4. Conclusion

The seasonal variations of ionospheric propagation characteristics of radio waves in the VLF, LF, MF and HF bands have been critically examined. Seasonal variations of LF, MF and HF radio signals show an anomalous maximum in signal strength in summer along with usual maximum in winter. The usual maximum in winter is due to the solar zenith angle dependence of the effective ionization flux affecting the ionization of the absorption levels, while the anomalous additional maximum which is more predominant in summer than in winter appears to be related to the diffusion of hydrated cluster of positive ions from the mesospheric/stratospheric heights to D-region heights. Such a trend is prominent in tropical regions because both the water vapour content and the surface water vapour density are significantly higher in summer than in winter in those regions.

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References

1. Belrose J S, *Low and very low frequency radio wave propagation*, Advisory Group for Aerospace Research and Development, North Atlantic Treaty Organization, July 1968.
2. Thomas L J, *J. atmos. terr. Phys.*, 37 (1975) 595.
3. Mitra S N, *J. Instn electron. telecommun. Engrs, New Delhi*, 23 (1977) 391.
4. Hollingsworth J, *J. Instn elect. Engrs*, 64 (1926), 579.
5. Bracewell R M, *Proc. Instn elect. Engrs*, 99 (1952), 217.
6. Straker T W, *Proc. Instn elect. Engrs*, 102C (1955), 122.
7. Weekes K & Stuart R D, *Proc. Instn elect. Engrs*, 92 (1952), 29.
8. Appleton E V & Piggott W R, *J. atmos. terr. Phys.*, 5 (1954), 141.
9. Schwentek H, *J. atmos. terr. Phys.*, 25 (1963), 773.
10. Lauter E A, Sprenger K & Entzean G, *Stratospheric Circulation*, edited by W L Webb (Academic Press, New York), 1969, 401.
11. Van Meter, *Tech. rep. No.* 12, The Pennsylvania State College, Pennsylvania, USA, AMC Contract No. AF 19 (122)-44, 15 June 1950.
12. Benner A H, *Tech. rep. No.* 15, The Pennsylvania State College, Pennsylvania, USA, AMC Contract No. AF 19 (122)-44, 31 July 1950.
13. Benner A H, *Tech. rep. No.* 18, The Pennsylvania State College, Pennsylvania, USA, AMC Contract No. AF 19 (122)-44, 15 Jan. 1951.
14. Bornholdt J W & Jackson T T, *Tech. rep. No.* 21, The Pennsylvania State College, Pennsylvania, USA, AMC Contract No. AF 19 (122)-44, 30 Mar. 1951.
15. Nerthney R J, *Tech. rep. No.* 28, The Pennsylvania State College, Pennsylvania, USA, AMC Contract No. AF 19 (122)-44, 20 Sep. 1951.
16. Kotadia K M, Kotak R M & Datta G, *Seasonal and solar cycle variations in the mesosphere and lower ionosphere found from ground-based radio wave absorption measurements*, Paper presented at the National Space Sciences Symposium held at Banaras Hindu University, Varanasi, during 22-25 Jan. 1980.
17. Somayajulu Y V & Dhanulu M B, *Indian J. Radio Space Phys.*, 1 (1972), 81.
18. Sechrist (Jr) C F, *Radio Sci.*, 5 (1970), 663.
19. Reid G C, *J. geophys. Res.*, 75 (1970), 2551.
20. Thomas L J, *J. atmos. terr. Phys.*, 38 (1976), 61.
21. Mitra A P, *Ionospheric effects of solar flare* (D Reidel Publishing Co. Ltd., Dordrecht, Holland), 1974.
22. Mitra A P, *Indian J. pure appl. Phys.*, 8 (1970), 507.
23. Thomas L, *J. atmos. terr. Phys.*, 88 (1976), 1345.
24. Uppal G S, Dubey Vandana & Chadha R, *J. Instn elect. telecommun. Engrs*, 25 (1979), 498.
25. Howe G M, *Weather, Lond.*, 11 (1956), 74.
26. Aro T D, *J. atmos. terr. Phys.*, 38 (1976), 565.
27. Fedynsky A V & Yushkov V A, *Direct measurements of water vapour concentration in the stratosphere and mesosphere in the equatorial zone and middle latitudes*, Paper presented at the COSPAR 22nd planetary meeting held at Bangalore during 29 May-9 June 1979.