Contribution of mesospheric ozone variability to the diurnal asymmetry in D-region electron density*

T. Arunamani, T. S. N. Somayaji and D. N. Madhusudhana Rao

Department of Physics, Andhra University, Visakhapatnam 530 003, India

Numerical calculations based on a one-dimensional time-dependent minor neutral constituent model coupled with an appropriate ion-chemical scheme showed that an asymmetry exists in the diurnal variations of electron density as well as ozone concentrations in the mesosphere. The striking similarity between the diurnal variations of the two species suggests that ozone plays an important role in the D-region ion-chemical scheme and contributes significantly to the diurnal asymmetry in D-region electron density.

THE asymmetry in the diurnal variation of electron density in the D-region of the ionosphere is one of the important problems awaiting satisfactory explanation. Rocket as well as ground-based (partial reflection and cross-modulation) measurements have shown that afternoon electron densities are generally greater than forenoon values for the same zenith angle[1–3]. Diurnal variation of radio wave absorption too shows a similar feature[4]. Greater morning values of electron density have also been observed occasionally[4,5]. The principal source of ionization in the D-region, nitric oxide (NO), owing to its long lifetime, is not expected to exhibit any diurnal variation. In the absence of any change in production due to NO, Chakrabarty *et al.*[6] sought to explain the diurnal asymmetry in terms of a probable asymmetry in temperature affecting the chemical loss rates. However, as pointed out by Chakrabarty *et al.*[6], it is doubtful whether such an asymmetry exists in the diurnal variation of temperature in the mesosphere.

Recently, the role of ozone in influencing the ionization balance and variability in the mesosphere is being increasingly demonstrated. For example, Arunamani *et al.*[7] observed similarities in the seasonal variation of LF propagation parameters and ozone concentrations. Further, not very long ago, model studies[8,9] showed that ozone concentration, besides exhibiting a day to night change, varies in the course of a day at mesospheric altitudes. In the light of these observations, we report here the results of a study of the diurnal variation of electron and ozone concentrations in the D-region basing on minor neutral species concentrations derived from a numerical one-dimensional time-dependent model of the upper middle atmosphere.

Somayaji and Arunamani[10] developed a one-dimensional time-dependent minor neutral constituent numerical model which gives the vertical distribution of odd-oxygen, hydrogen and nitrogen species in the 60–120 km range. In order to obtain the electron density profiles, the ion chemical scheme of Reid[11] has been used in conjunction with the above neutral minor constituent model. The required radiation fluxes, ionization and absorption cross-sections of a variety of member species have been taken from the literature[12]. The model calculations give ion and electron concentrations and their vertical distributions at different times of the day. The results pertain to equinox at low latitudes for solar minimum conditions.

Electron and ozone concentrations at different heights in the D-region as a function of solar zenith angle are shown in Figure 1. The dissimilar forenoon and afternoon variations of these two species concentrations establish the asymmetry about noon. The concentrations of both species in the afternoon are smaller than the forenoon values at 78 km and below. On the other hand, the afternoon concentrations are greater than the forenoon values above 78 km. The asymmetry in the diurnal variation begins to weaken at around 84 km and above 90 km there is no evidence of asymmetry. The striking similarity between the diurnal variations of electron and ozone concentrations shows that ozone plays an important role in the D-region ion-chemical scheme. It is useful to examine this in some detail.

It is well known that besides NO, the metastable oxygen molecule, $O_2(^1\Delta_g)$, is an important source of free electrons in the D-region[13]. The $O_2(^1\Delta_g)$ is produced by photodissociation of ozone:

$$O_3 + h\nu \xrightarrow{\leq 310\,\text{nm}} O_2(^1\Delta_g) + O(^1D).$$

The $O_2(^1\Delta_g)$ contributes to free electrons not only through photoionization

$$O_2(^1\Delta_g) + h\nu \xrightarrow{102.7\text{–}111.8\,\text{nm}} O_2^+ + e$$

but also through electron detachment:

$$O_2^- + O_2(^1\Delta_g) \rightarrow e + 2O_2.$$

Further, atomic oxygen produced by photodissociation of ozone contributes to free electrons through the following associative detachment reactions:

$$O_2^- + O \rightarrow O_3 + e \quad \text{and}$$

$$O^- + O \rightarrow O_2 + e.$$

Thus, a variation in ozone concentration leads to a

*Paper presented at the 8th National Space Science Symposium (NSSS-94) held at VSSC, Trivandrum, India.

similar variation in electron density. The asymmetry observed in numerically calculated O_2^+ concentrations shown in Figure 2 (which also shows the zenith angle variation of the total negative ions) lends support to this argument.

Besides photo-chemical processes, dynamical forcing arising from winds and tides are expected to influence the diurnal variability of species concentrations in the mesosphere. Bjarnason *et al.*[14] developed a one-dimensional mesospheric minor constituent numerical model with and without including the tidal forcing on vertical diffusion. They found that a diurnal asymmetry similar to that observed in the one-dimensional model adopted by us, exists in the ozone concentrations when tidal forcing was excluded. Consideration of the tidal effect resulted in an accentuation of the asymmetry. It thus appears from the above results that the asymmetry in the diurnal variation of mesospheric ozone is an important factor contributing to the diurnal asymmetry in the D-region electron density. The reversal in the asymmetry in electron density, observed at 78 km, from morning to afternoon similar to that seen in ozone variation as well, is interesting. However, to trace the reasons for this involves a detailed study of ozone chemistry and

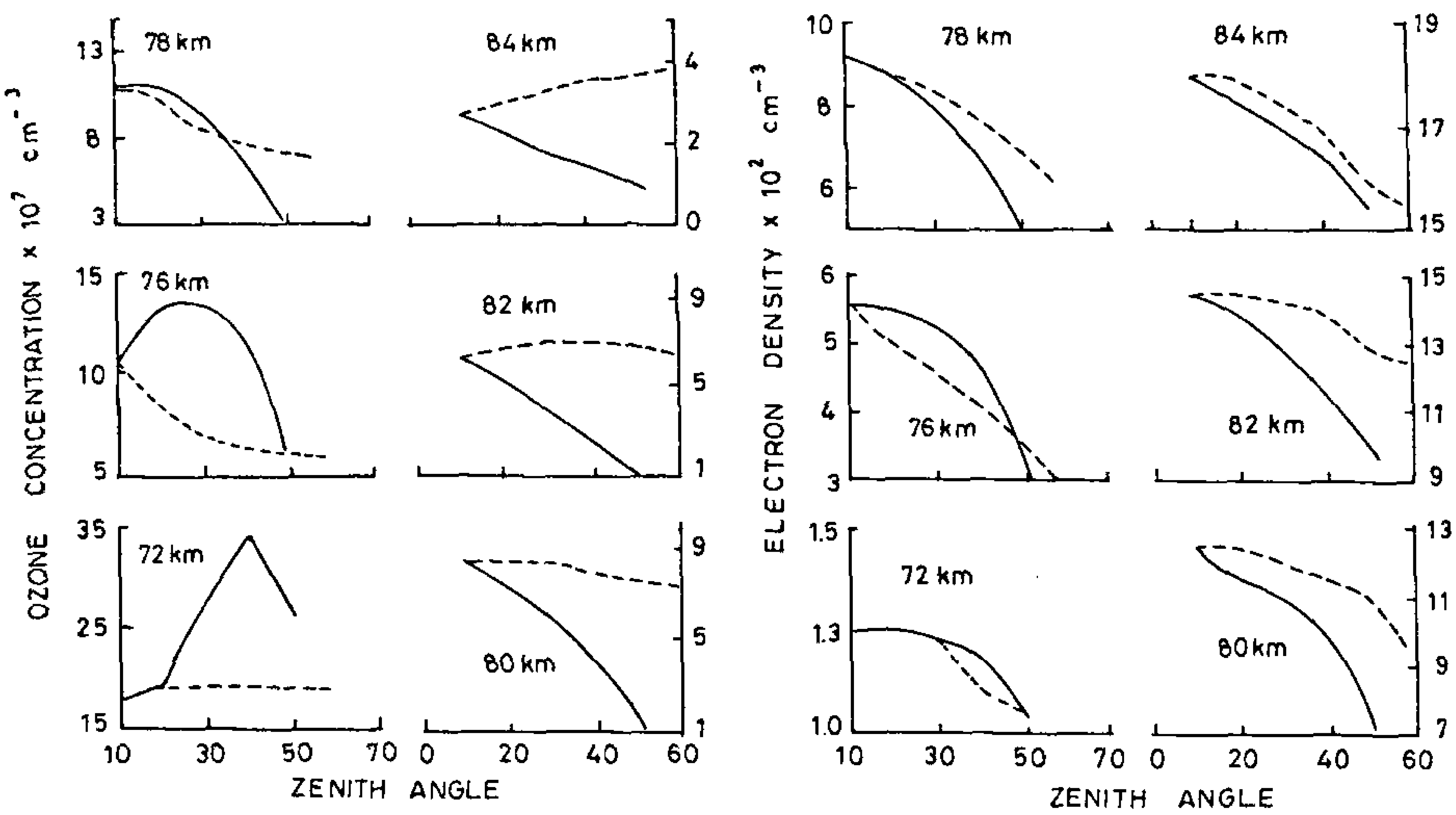

Figure 1. Zenith angle variation of ozone and electron concentrations (full line, forenoon; broken line, afternoon).

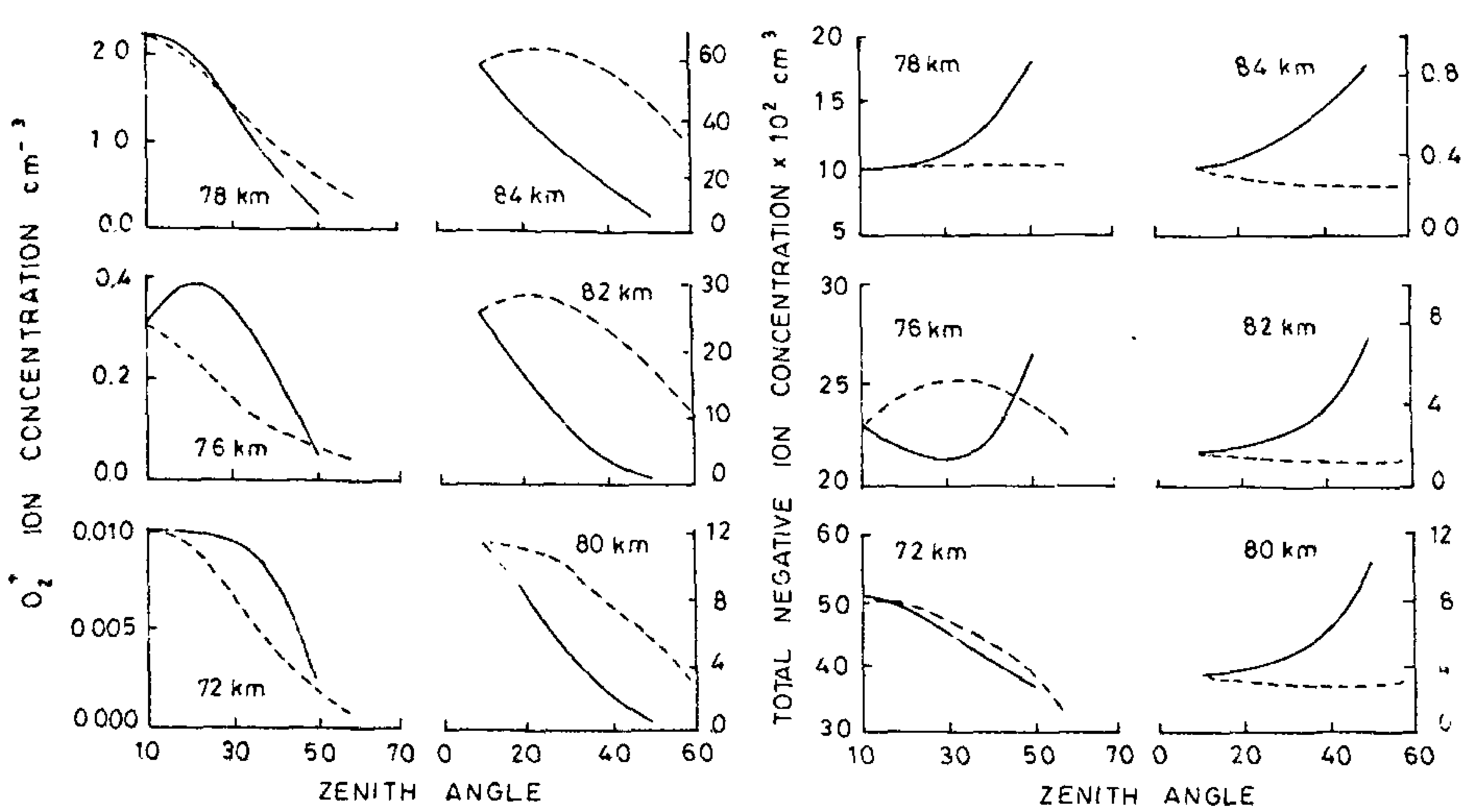

Figure 2. Zenith angle variation of O_2^+ and total negative ion concentrations (full line, forenoon; broken line, afternoon).

variation in vertical eddy diffusion which is being carried out and the results will be published elsewhere.

1. Aikin, A. C., Goldberg, R. A., Somayajulu, Y. V. and Avadhanulu, M. B., *J. Atmos. Terr. Phys.*, 1972, **34**, 1483–1494.
2. Haug, A. and Thrane, E. V., *J. Atmos. Terr. Phys.*, 1970, **32**, 1641–1647.
3. Coyne, T. N. R. and Belrose, J. S., *Radio Sci.*, 1972, **7**, 163–174.
4. Lastovicka, J., *J. Atmos. Terr. Phys.*, 1977, **39**, 891–894.
5. Thomas, L., *COSPAR Methods of Measurements and Results of Lower Ionospheric Structure* (ed. Rawer, K.), Akademy Verlag, 2974, pp. 153–167.
6. Chakrabarty, D. K., Meek, C. E. and Manson, A. H., *J. Atmos. Terr. Phys.*, 1983, **45**, 309–314.
7. Arunamani, T., Somayaji, T. S. N., Rao, D. N. M. and Ramana, K. V. V., *Curr. Sci.*, 1990, **59**, 738–740.
8. Allen, M., Lunine, J. I. and Yung, Y. L., *J. Geophys. Res.*, 1984, **89**, 4841–4872.
9. Somayaji, T. S. N. and Arunamani, T., *Indian J. Radio Space Phys.*, 1988, **17**, 220–231.
10. Somayaji, T. S. N. and Arunamani, T., *Indian J. Radio Space Phys.*, 1990, **19**, 154–165.
11. Reid, G. C., *Adv. At. Mol. Phys.*, 1976, **12**, 375–413.
12. Arunamani, T., Ph D thesis, Andhra University, Visakhapatnam, 1983.
13. Hunten, D. M. and McElroy, M. B., *J. Geophys. Res.*, 1968, **73**, 2421–2428.
14. Bjarnason, G. G., Soloman, S. and Garcia, R. R., *J. Geophys. Res.*, 1987, **92**, 5609–5620.

ACKNOWLEDGEMENTS. We are grateful to Prof. K. V. V. Ramana for his interest in this work and helpful suggestions.

Received 17 October 1995; revised accepted 8 February 1996

Watermolds: Potential biological control agents of malaria vector *Anopheles culicifacies*

G. S. Bisht*, Chandra Joshi and R. D. Khulbe

Department of Botany, Kumaun University, Nainital 263 002, India
*Present address: Vivekananda Parvatiya Krishi Anusandhan Shala, Almora 263 601, India

***Leptolegnia caudata* and *Aphanomyces laevis* (Saprolegniales: Oomycetes) were found for the first time as naturally occurring parasites of mosquito larvae, causing high mortality in *Anopheles culicifacies* larvae. Artificial inoculation under laboratory condition revealed *L. caudata* more pathogenic, caused 100% mortality within 7 days of inoculation as compared to *A. laevis* (70% mortality after 10 days). None of these is pathogenic to any crop and have no toxic effect on aquatic fauna, and thus, can be proposed as mosquito control agents, alternative to chemical insecticides. Mass culture of these pathogens, preferably *L. caudata* can be applied in major larval habitats for long term, non-hazardous, economically sustainable control of malarial vector *A. culicifacies*, thereby malarial transmission.**

MALARIA, caused by *Plasmodium* spp. (Protozoa) is the most important insect-transmitted human disease of the tropics and subtropics. Two to three million people die from malaria each year[1]. In India, more than two million clinical cases are reported annually[2]. Of the four recognized human parasites that cause malaria, three (*P. falciparum*, *P. malariae* and *P. vivax*) are found in India, and *P. falciparum* as elsewhere[1] is most pernicious[2], whereas *Anopheles culicifacies* (Diptera: Culicidae) is the most important vector and accounts for about 70% malaria cases in the country[2].

The super-resistant strains of *Plasmodium* spp. which appeared in Colombia and Thailand in the seventies are spreading. Because of these drug-resistant strains of parasites and insecticide resistance of the vectors[1–5], malaria has posed a renewed threat, and thus has warranted research for novel and cost-effective, non-hazardous control measures[2,6]. Besides larvivorous fishes[1,7,8] and nematodes, several species of viruses, protozoa and fungi[9] are known to parasitize mosquito larvae, but none of these proved efficient as well as economical for malaria control[9]. However, *Lagenidium gigantum*, a zoosporic fungus, has been registered for its use as a biocontrol agent of mosquitoes belonging to genera *Anopheles*, *Aedes*, *Culex*, *Culiseta* and *Psorophora*[10]. In view of the malaria problem, a study was conducted to explore pathogenic association of watermolds with mosquito larvae in a malaria-prone zone of UP hills, in order to exploit it for malaria control.

Sampling of *Anopheles* larvae was done during the rainy season from irrigation channels, paddy fields and from river Gaula, between Haldwani and Santipuri in Nainital district, UP (29°55′N and 70°40′E; 400 msl), with the technical assistance of Malaria Research Centre, Haldwani. Invisible disease symptoms were observed with a powerful hand lens and compound microscope. Symptomatic/dead *A. culicifacies* larvae were immediately brought to the laboratory and the associated fungal species were isolated by placing boiled hemp seed (*Cannabis sativa* L.) halves in close contact with larvae, treated with 0.01% potassium tellurite solution (v/v) and duly rinsed with sterilized water. Fungal species from water were isolated by baiting with boiled hemp seed halves. Treated larvae were also inoculated onto potato dextrose agar media (PDA). The inoculated PDA plates and baited petri plates were incubated at 20 ± 1°C and the unifungal culture of the pathogen(s) that colonized on the baits and on PDA was prepared; purified following Raper[11]. Stock cultures were maintained on PDA for further investigation.

Pathogenicity of the isolates was tested under