Off–Shore Sea Surface Electric Field Investigations around the Indian Sub–Continent during 9–20 May 1983

G. K. Manohar, S. M. Sholapurkar and *S. S. Kandalgaonkar*
Indian Institute of Tropical Meteorology, Pune 411 008, India
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ABSTRACT

Sea surface electric field observations off the coast from Goa (15°25′N, 73°47′E) to Madras (13°04′N, 80°15′E) around Sri Lanka, in a distance range 25–135 km from coast, during 9–20 May 1983 were taken. In this paper we have examined the diurnal variation of electric field in the Arabian Sea, Indian Ocean and Bay of Bengal regions covered during the cruise of the research ship ORV Gaveshani. An aspect of electric field dependence on coastal distance and Aitken Nuclei concentration has also been studied. An attempt to examine the latitude dependence of field was also made. Results obtained in the above studies are presented and compared with those obtained elsewhere.

I. INTRODUCTION

It is generally believed that the measurements of electric parameters of the atmospheric surface layer over oceans will, in principle, lead to a better understanding of the various processes that influence them as well as the global atmospheric phenomena than the measurements over the land surface (Cobb, 1977). A review of the past work indicated the Carnegie cruise observations during 1915 to 1929, Ruttenberg and Holzer′s (1955), Takagi and Kanada′s (1969, 1970) and Misaki and Takeuti′s (1970) observations over Pacific Oceans and Muhleisen′s (1967) over the Atlantic. When summarised, their results revealed that the electric field and the air conductivity varied with increase in distance from the coast and perceptible diurnal variation over oceans were not noticed. Also, the global pattern of the electric field, first recognized during the Carnegie cruise experiments was once again identified during the long duration–fair–weather–open sea experiments (Morita, 1971, Kasemir, 1972 / VIII). Sea surface observations of electric parameters in the Indian region appeared to be very limited. Observations which came to the author′s notice were only of Mani et al. (1972 / VIII) and kolokolov (1981) which were in the Bay of Bengal and Indian Ocean respectively. Mani′s (1972 / VIII) observations of field were taken only during the afternoon hrs between 1400–1500 hrs IST. During this interval the average field, at large distances in the range 200–300 km from the coast, was 66 Vm^{-1} which was varying in the limits 24–94 Vm^{-1}. Near Madras and Vishakhapattanam (17°41′N, 83°18′E), the field variation was peculiar. At Madras field was 104 Vm^{-1} whereas at Vishakhapattanam it was 42 Vm^{-1} only,. However, a common feature of the observations was the reduction in field with increase in coastal distance. Kolokolov (1981) examined the electric field observations over the open seas of the Indian ocean and could identify the existence of unitary variation in field.

In a different study by Ramanadham et al. (1984) observations of field were taken at the shore line of Vishakhapattanam beach. Their study showed a pronounced diurnal variation in field associated with on–shore and off–shore winds. It appeared that measurements of sea surface electric parameters in the past in the Indian region, like those reported over Pacific / Atlantic Oceans, were very limited.

The present observations, although are of short duration, and have proximity to the coast line, may be found useful as they present important information and reveal the limitations of the experiments.

Results in the present study, since the research ship ORV Gaveshani was taken mostly parallel to the coast–line in a distance range 25–135 km around the Indian sub–continent in fair weather conditions, represent tropical marine off–shore electric conditions.

II. INSTRUMENTATION, INSTALLATION AND COURSE OF THE CRUISE

Electric field was monitored by using P_0–210, 6 μ Ci collector as a potential equalizer placed at 166 cm height over a plane level surface of the top deck and an electrometer operational amplifier through 10^{12} ohm resistance and 100:1 voltage divider. The minimum value of the electric field which the instrument could record was 2 Vm^{-1} in the highest sensitivity range. The instrument was checked for zero and calibration was done before the start and end of the observations. During the field measurements no attempt could be made to find out the reduction factor (Mani et al., 1972 / VIII; Takagi and kanada, 1972 / VIII and Cobb, 1977) for the experimental set–up. Details of the instruments are described elsewhere (Selvam et al., 1977). Continuous record of field was taken on 1 mA strip chart recorder run at speed 1 cm per minute. The complete set–up was placed on the top deck above the navigation bridge at ~ 10 m above the sea surface. The observation spot was well apart from the draft or stacks in the bow direction to keep the measurements free from the ship's pollution (Misaki and Takeuti, 1970; Morita and Ishikawa, 1977). The average sailing speed of the ship was ~ 6–10 km per hour.

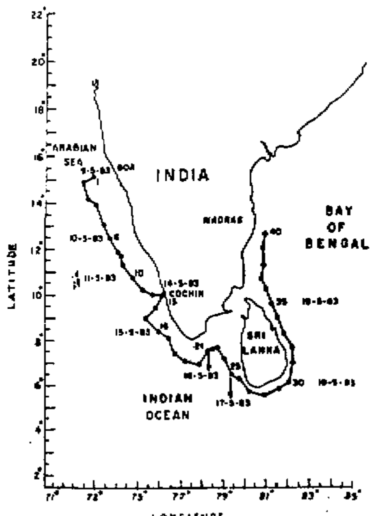

Fig.1. Course of the ORV Gaveshani from Goa to Madras during 9–20 May 1983. In this figure the numbers 1,6,10,··· 40, denote the positions of the ship; dates and sea regions are also shown for reference along the path of its cruise.

The research ship left Goa on the night of 8th May and reached Madras on 20th May 1983 in the afternoon hrs. In between, from 1200 hrs. of 11.5. 1983 to 1600 hrs of 14.5. 1983 the ship was at halt in Cochin (09°58′N; 76°14′E) harbour. Records of field were initiated from 0800 hrs of 9.5. 1983 and continued upto 0800 hrs of 20.5 1983. The observations of the electric field pertaining to halt period at Cochin harbour were not considered in the present work since the observations were seen vitiated by the exhausts from the marine traffic and, local pollution (Uchikawa, 1972; W. M. O., 1978; Manohar et al., 1989) which would not represent clear air, fair weather electric field records. The weather conditions during the entire period of observations remained fair with generally clear skies except occasional 1–2 / 8 Sc–Cu. The sea was generally calm and wind was very light.

Fig.1 shows the course of the cruise. In this figure the numbers 1, 6, 10,⋯40; dates and sea regions are shown for reference along the path of the cruise. Table 1 gives the dates, times, the nearest distance (Misaki and Takeuti, 1970) of the ship and hourly average field for positions (3 to 40).

III. DATA

Form the continuous records of electric field, data at 10 minute interval were picked up and used to compute hourly average values of field by considering three values on either side of the hour and the hourly value itself. The other data used in the present study were the sea surface atmospheric pressure and the surface wind. This data was obtained from the ship authorities. Using the above data the following aspects of electric field variations were examined.

Table 1. Details of Positions, Dates, Times, Distances from the Coast and Average Electric Field at the Positions (3–40) for the Course of Ship during 9–20 May 1983

Position No.	May 1983 dates	Time IST	Distance Km	Electric field Vm^{-1}	Position No.	May 1983 dates	Time IST	distance Km	Electric field Vm^{-1}
1	9	0000	85		21	16	0300	102	36
2	"	0500	132		22	"	0800	95	50
3	"	1000	137	40	23	"	1700	87	61
4	"	1500	126	24	24	"	2200	70	41
5	"	2000	114	30	25	17	0300	53	78
6	10	0100	102	27	26	"	0800	26	126
7	"	0600	94	36	27	"	1300	26	125
8	"	1600	91	34	28	"	1800	41	100
9	"	2100	111	53	29	"	2300	32	82
10	11	0200	102	86	30	18	0400	38	79
11	"	0700	79	112	31	"	0900	17	131
12	11	1200	Ship in Harbour	Ship in Harbour	32	"	1400	29	120
13	14	1200	"	"	33	18	1900	26	105
14	"	1600	"	"	34	19	0000	29	97
15	14	2100	97	51	35	"	0500	81	78
16	15	0200	73	73	36	"	1000	67	65
17	"	0700	55	78	37	"	1500	64	54
18	"	1200	79	85	38	19	2000	76	22
19	"	1700	91	66	39	20	0100	59	111
20	15	2200	137	46	40	20	0600	50	86

1. *Diurnal Variation of Electric Field*

To examine the above aspect the course of the ship (Fig 1) was divided into three sea regions.

(1) Arabian Sea A: (Position 1–17)

(2) Indian Ocean I: (Positions 17–32)

(3) Bay of Bengal B : (Positions 32–40)

2. *Electric Field Variation with Coastal Distance of the Ship and Aitken Nuclei (A.N.) Concentration*

Ship's position–wise (3 to 40) distances and the average field values (Table I) and A.N. concentrations were used in this analysis. Informations on A. N. concentration were obtained from Khemani et al.(1985a) who took these simultaneous observations along the same cruise.

3. *An Examination of Latitude Dependence of Electric Field*

Electric field values at the diurnal maxima times during 9 to 17 May between positions 1–28 were noted and their departures from the regional field maxima in the Arabian Sea,.Indian Ocean and also the latitudes and coastal distances were noted. Similar procedure was followed for ship between positions 29–40 during 18–20 May in Bay of Bengal. These notings accomplished two sets of observations of departures of field, latitudes and coastal distances in the Arabian Sea and Bay of Bengal regions.

For the possible elimination of simultaneous influence of diurnal and coastal distance variation on field this procedure was necessary. Procedures consistent to their observations were followed elsewhere (Gish, 1942; Morita, 1971;Takagi and Kanada, 1972 / VIII) for an examination of latitude dependence of electric field.

IV. RESULTS

1. *Diurnal Variation of Electric Field*

The off–shore sea surface electric field records were analysed to examine the diurnal variation in the three: A, I, B regions (Fig. 2). The following features were noticed:

In the Arabian Sea the diurnal variation was seen to be typical one with maxima (90 Vm^{-1}) reaching around 0800 hrs IST. It was noticed that on either side of the maxima the field decreased and remained nearly steady (50 Vm^{-1}) throughout. The minimum field (40 Vm^{-1}) was reached around 1200 hrs IST.

In the Indian Ocean and Bay of Bengal regions the trends appeared to be comparable. Initially the field increased gradually, then reached maxima and subsequently slowly decreased with time. Also, it exhibited a double oscillation in both regions unlike in the Arabian Sea. Even though the trends of diurnal variations of field in the two regions are comparable, the time of the first maxima (120 Vm^{-1}) in Indian Ocean was around 0800 hrs IST and in the Bay of Bengal 0400 hrs IST. The time of the second maxima (90 Vm^{-1}) in the two regions was the same, being 1400 hrs IST. The minimum field in the two regions were 50 Vm^{-1} and 30 Vm^{-1}, respectively, around 1900 almost simultaneously.

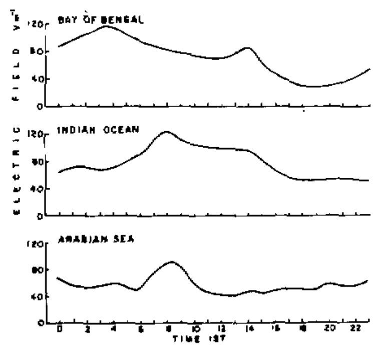

Fig.2. Diurnal variation of electric field in the three sea regions: Arabian Sea, Indian Ocean and Bay of Bengal.

The mean values of field in the three sea regions were 60,80 and 70 $Vm^{-1}$with standard deviations 20,28 and 28 respectively and the diurnal ranges of field variations were 50, 70 and 90 Vm^{-1}respectively. These results are shown in Table 2.

Table 2. Characteristics of Diurnal Variation of Sea Surface Electric Field in the Three Sea Regions

Characteristics of diurnal variation of sea surface electric field (Vm^{-1})					Sea regions
Maximum	Minimum	Mean (Std)	Diurnal range	Nature of variation	
90 (0800) IST	40 (1200) IST	60 (20)	50	Typical, field decreasing on either side of maxima	Arabian Sea from positions 1–17 during 9–15 May 1983
120 / 90 (0800 / 1400) IST	50 (1900) IST	80 (28)	70	Double oscillation	Indian Ocean from positions 17–32 during 15–18 May 1983
120 / 90 (0400 / 1400) IST	30 (1900) IST	70 (28)	90	——do——	Bay of Bengal from positions 32–40 during 18–20 May 1983

Net average electric field in the Indian sub–continent 75 vm^{-1}

2. *Electric Field Variation with the Coastal Distance of the Ship and Aitken Nuclei (A. N.) Concentration*

Figure 3 shows the distribution of electric field with respect to the distance from the coast using values from Table 1. The X axis shows the ship's positions from 1–40, dates and the sea regions covered by the ship during the cruise. At the top of the figure is shown the prevailing winds and sea surface pressure. The wind direction was plotted in an usual convention but the wind speeds were drawn according to our convenience (1 feature for 1 knot) since the wind speeds observed during the period were around 2–3 knots only. The ordinates on the left side show scales for electric field (F) and pressure and that on the right shows distance (D) from the coast. At positions 12–14 the ship was in harbour and the data during this period was not considered as already explained earlier.

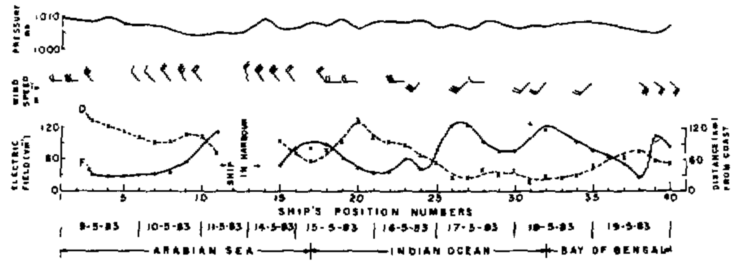

Fig.3. Electric field variation with coastal distance of the ship: using data from Table 1. Prevailing surface wind and pressure are also shown at the top of the figure.

We notice from F–D curves that as the ship's distance from the coast started increasing the field started declining and vice–versa. The inverse behaviour between F–D was noticed clearly between positions 3–20 and 30–40. The correlation coefficient between F–D values for the total 35 positions was found to be –0.78 which was highly significant (1% level). In Fig.4 is shown the plot of variation of average field against average distance in 10 km width using data from Table 1. In the same figure the corresponding average concentrations of A.N. (Number per cm^3) are also shown. Above features clearly indicated the extension of influence of land origin aerosols on electric field (Takagi and Kanada, 1969; Misaki and Takeuti, 1970; Mani et al., 1972 / VIII; Takagi and Kanada, 1972 / VIII; Morita and Ishikawa,1977).

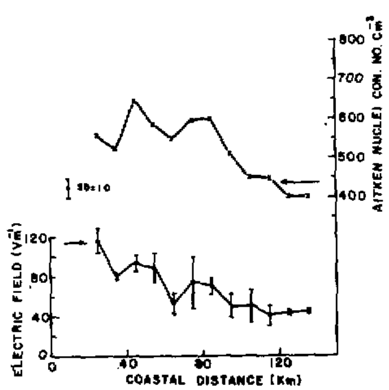

Fig.4. Variation of average field and A. N. concentration versus average coastal distance in 10 km width using data from Table 1.

Another interesting feature observed from the figures 3 and 4 was that the electric field and A. N. concentration appeared to be reasonably steady beyond a distance of ~ 80 km from the coast. Considering that the wind direction was mostly from the seas towards the land all throughout and that wind speed was also nearly steady, it was inferred that the extension of land origin pollutants over the seas under prevailing winds was fairly steady. This distance could be reckoned as the range for background pollution in the Indian–sub–continent. Results analogous to this study but consistent to their experimental conditions were obtained (Takagi and Kanada, 1969; Misaki and Takeuti, 1970 ; Morita, 1971; Morita and Ishikawa, 1977). The correlation coefficient (–0.1965) between field and atmospheric pressure was not significant which suggested a weak negative dependence of the two parameters(W.M.O. Tech. Note No. 162, 1978).

3. *An Examination of Latitude Dependence of Electric Field*

As explained earlier, in Fig. 5 the departures in the daily field maxima from the regional maxima in the Arabian Sea and Bay of Bengal regions were plotted against latitude. Coastal distances of the points were also shown along the two curves. An inspection of the curves for the two sea regions indicated a gradual change taking place in the departures of field from initial positive towards negative. This change was maximum around latitude 10°N. This feature was noted almost concurrently in both the seas. The values of departures of field in the lower latitudes (10°to 5°N) should also have been higher negative as believed, considering the closer proximity of observations to the coast. However it did not happen so. This feature of the electric field suggested that around 10°N in the open oceanic regions the fair weather sea surface electric field may be experiencing a maximum.

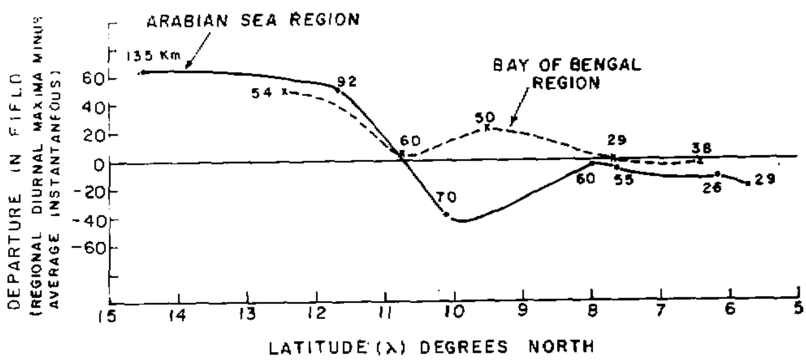

Fig.5. Departures in the daily maximum field from the regional maxima in the Arabian Sea and Bay of Bengal regions plotted against latitude (λ). The numbers in the figure denote the coastal distance of the ship at those points.

V. DISCUSSIONS

(1) Information on diurnal pattern, minimum, average, maximum value and diurnal range of field in the three sea regions was furnished earlier. A comparison of the average field values 110,95 and 90 Vm^{-1} respectively (Takagi and Kanada, 1970; Carnegie; Morita, 1971) with the present value 75 Vm^{-1} indicated that this was on the lower side. However, when this value was compared with Mani et al., (1972 / VIII), 66 Vm^{-1}, it appeared acceptable.

The range of diurnal variation of field (50 to 90 Vm^{-1}) in the present study was within acceptable limits in comparison to land values (which is certainly much higher) since over the oceans radioactive ionization is far less, small ion equilibrium exists and also where meteorological processes do not undergo regular or extreme changes (Brown, 1935; Kikuchi, 1970; Shimo et al., 1972 / VIII; Selvam et al., 1980).

We have noticed that field variation in Arabian Sea was different from the other two regions. The dependence of surface electric field on air–mass or aerosol characteristics was discussed at length (Bharatendu, 1969; Koenigsfled, 1971; Shimo et sl., 1972 / VIII; Uchikawa, 1972 / VIII; Selvam et al., 1980). Their results pointed out that for expecting a comparable pattern in field at two or more stations, it is essential that the stations should fall under similar air–mass / aerosol regimes. In a study of simultaneous observations of trace elements, Sea salt aerosol and A. N. (Khemani et al., 1985,1985a) it had been shown that the two regions (Arabian sea and Bay of Bengal) were different on the above two points. In the present observations also it was noticed that the average field value over Arabian Sea was lower than that over Bay of Bengal (Table 2). This observation also seems to be consistent as the average concentration of A. N. and T. S. P. respectively over Arabian Sea was 10% and 50% lower than that over Bay of Bengal (Khemani et al., 1985a, 1985). Since the level of aerosol concentration and its diurnal variation at a place considerably influences the electric field, our observations of field variation appear to be consistent and acceptable.

(2) The analysis of electric field variation with coastal distance and A. N. concentration has brought out two important results which are consistent with those of many others.

(3) As regards the dependence of the electric field on latitude it was inferred that in the open sea regions in fair weather conditions the sea surface electric field showed a maximum around 10°N. This result is based on short period observations and therefore long period observations may be necessary to come to a certain conclusion.

VI. CONCLUSIONS

Off–shore sea surface electric field observations in the Indian sub–continent during 9–20 May 1983 indicated as follows:

(1). The average sea surface electric field value over the three sea regions was 75 Vm^{-1} . This value was low compared to values in other oceanic regions, however it was in good agreement with the earlier value in the same region.

(2). Electric field variation with the coastal distance and Aitken Nuclei concentration indicated that for closer distances electric field was higher and vice–versa. This feature indicated an extension of land origin aerosols into sea regions. An arbitrary distance range of 80 Km from the coast was identified. This distance could be reckoned as the range of sea level background air pollution.

(3). On the basis of the limited data (period and latitudinal coverage) it was tentatively inferred that around 10°N the electric field showed a maximum , however, to arrive at any assertive conclusion regarding the latitude dependence of the electric field, long period observations may be necessary.

It is realized that the present observations, although they are of short duration and have proximity to the coast line, may be found useful as they presented important informations and revealed the limitations of the experiments which may be a guideline in future works.

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