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6. MIDDLE ATMOSPHERE ELECTRODYNAMICS (MAE)

6.1 MIDDLE ATMOSPHERIC ELECTRODYNAMICS DURING MAP

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The recent revival and strong motivation for research in middle atmospheric electrodynamcis can be attributed, in large part, to the discovery of large (V/m) electric fields within the lower mesosphere during the decade prior to MAP. Subsequent rocket soundings appeared to verify the preliminary findings. During the MAP era, more sophisticated techniques have been employed to obtain measurements which respond positively to criticisms of earlier results, and which provide more insight regarding the character of the fields. The occurrence of mesospheric V/m electric fields now seems to require the presence of aerosols, of local winds and related dynamics, and of an atmospheric electrical conductivity less than 10^{-10} S/m. Furthermore, new theoretical ideas describing the origin of the V/m fields are consistent with the measurements. The current status of results regarding V/m fields in the middle atmosphere is reviewed in light of the more widely accepted electric field structure for this region from rocket, balloon and modeling results.

WHAT IS MIDDLE ATMOSPHERE ELECTRODYNAMICS ?

- Study of the middle atmospheric electrical environment including :
  - Electric fields
  - Bulk ion properties
  - Charged aerosols
  - Free electrons
  - Current flow, etc.

- Recent problems under study include :
  - Existence and characteristics of large (V/m) **E** fields.
  - A.C. and D.C. **E** fields related to thunderstorms and lighting.
  - **E** field and plasma perturbations associated with waves and turbulence.
  - Modification of MAE parameters by high energy events such as REP's.

Figure 1. Middle atmospheric electrodynamics (MAE) is concerned with the study of the middle atmospheric electrical environment including electric fields, bulk ion properties, charged aerosols, free electrons, current flow, etc. It is particularly concerned with the manner in which these parameters affect middle atmospheric coupling with other regions of the near earth environment and on how the region affects transmission of electromagnetic waves or other electrical signals traveling through it. Many of the recent topics receiving attention through dedicated rocket and balloon programs are listed in the figure and will be discussed in further detail in the four review papers which follow. This paper concentrates on the evolution of our knowledge regarding the apparent large (V/m) electric fields which are occasionally observed in the lower mesosphere.

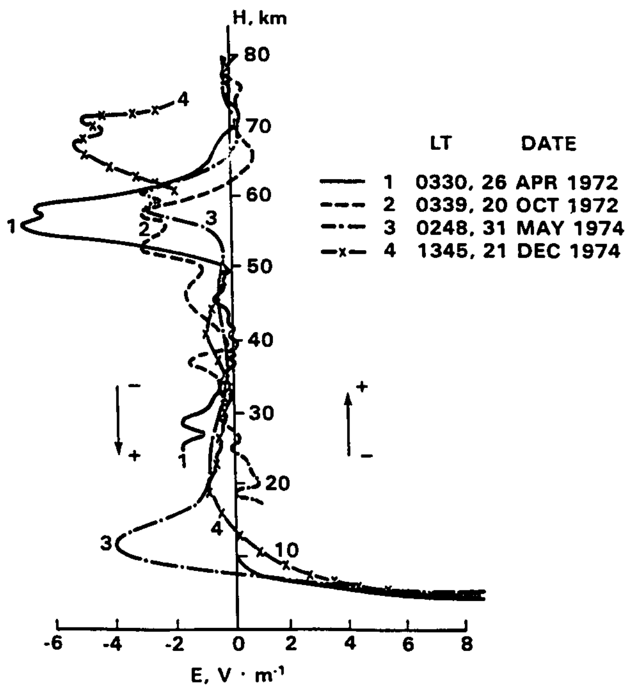

Figure 2. Discovery of the vertical V/m fields is attributed to Bragin et al. [1974] and Tyutin [1976], who reported four rocket measurements of them using field mills abroad the payloads. The figure displays three night and one day measurements, with the latter occurring at a higher altitude. The fact that all flights showed existence of the V/m field led the above authors to conclude that this was a permanent feature of the region, always contained within a region having a characteristic half width of about 10 km. Bragin, Yu. A., et al., *Cosmic Res., 12,* 279, 1974; Tyutin, A. A., *Cosmic Res., 14,* 132, 1976.

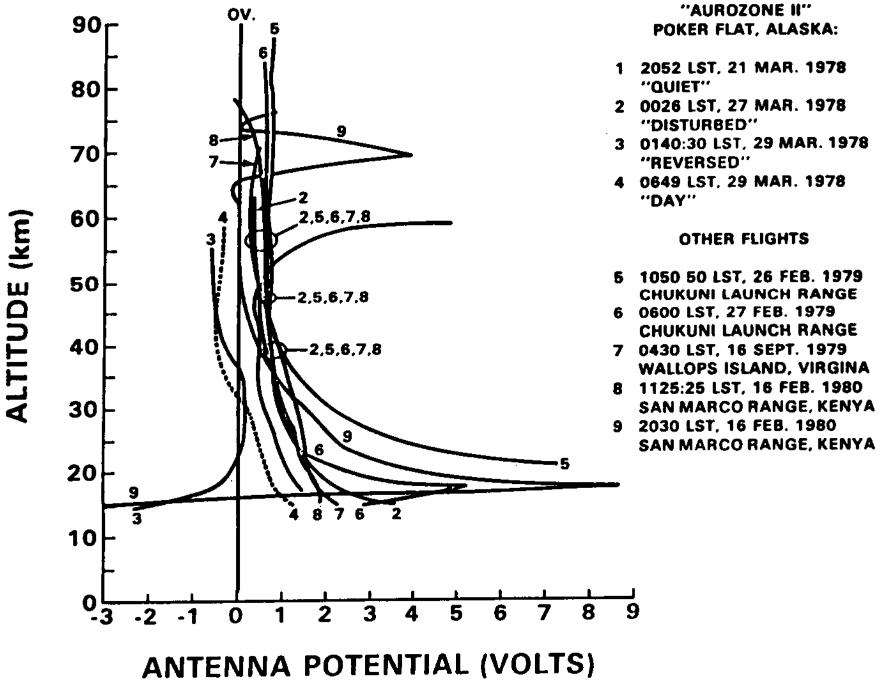

Figure 3. Hale et al. [1981] reported results of nine separate rocket flights carrying an asymmetric probe technique to measure vertical electric fields at several different locations, but could only detect V/m fields in two cases. They concluded that the fields were relatively in frequency, and certainly not a permanent feature of the region. Measurement of a vertical V/m field was also made by Maynard at Wallops Island, Virginia [Maynard et al., 1981] using a sophisticated three-dimensional boom-mounted probe array. Hale, L. C., et al., *Geophys. Res. Lett.*, *8*, 927, 1981; Maynard, N. C., et al., *Geophys. Res. Lett*, *8*, 923, 1981.

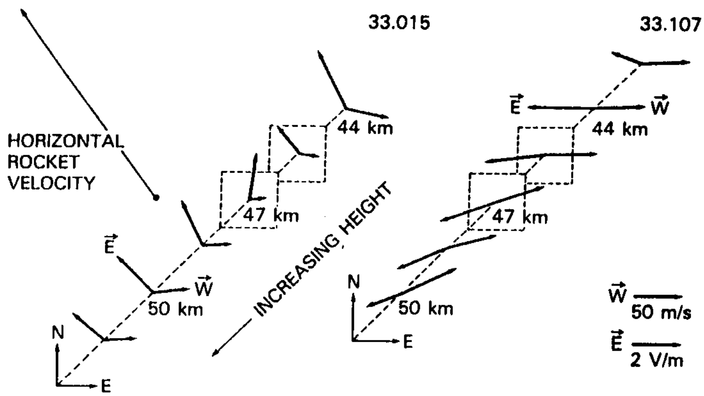

Figure 4. The first rocket measurements of large (V/m) horizontal electric fields were made on two separate nights at Andoya, Norway, in 1980 [Maynard et al., 1984]. The field directions (E) were found to anticorrelate with atmospheric wind directions (W) determined from simultaneous meteorological rockets. Furthermore, although energetic particle events were in progress during both measurements, the fields were observed to occur below those heights where significant ionizing radiations had penetrated, which helped contribute to the conclusion that electrical conductivities above 10^{-10} S/m would probably not support such fields. Maynard N. C., et al., *J. Atmos. Terr. Phys., 46*, 807, 1984.

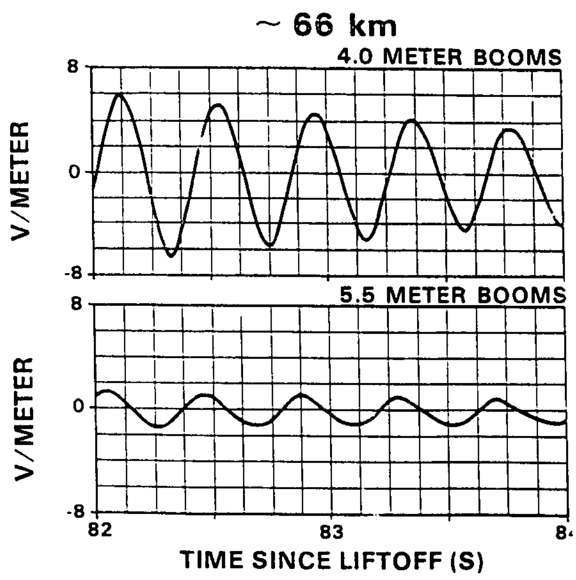

Figure 5. Kelley et al. [1983] also reported detection of an apparent V/m field near 66 km, using two sets of boom-mounted probes orthogonal to a rocket payload, each pair of different length. They found the field measured by the shorter booms to be of higher magnitude than that measured across the longer separation, leading them to conclude that the measurement was invalid, probably contaminated by wake effects and other sheath induced charge distributions. They al,so inferred that all previously reported measurements should be subject to closer scrutiny to establish their validity. Kelley, M. C., et al., *Geophys. Res. Lett., 10*, 733, 1983.

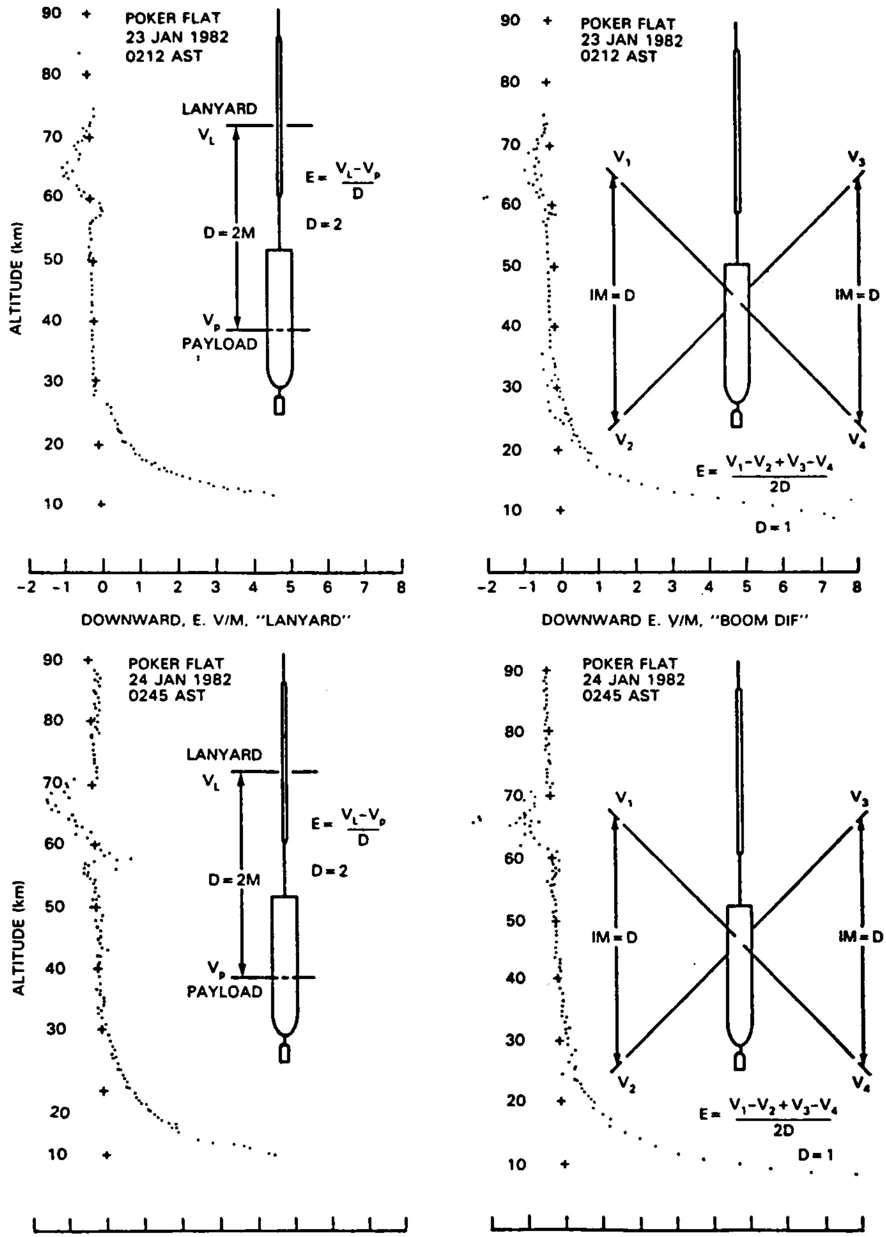

Figure 6. In defense of his earlier measurements, Hale [1984] showed two independent pairs of measurements made from Poker Flat, Alaska, in 1982. On each rocket, Hale measured vertical electric fields with both an asymmetric double probe and a symmetric boom-mounted probe technique. On both flights, each approach measured large vertical electric fields between 60 and 70 km of equivalent shape and magnitude, showing consistency between the two approaches. Later Maynard [1986] showed that an anomolously large electric field would be measured with his instrument prior to its detachment from the main rocket payload, but that once separated and in the normal operating mode, measurement values returned to anticipated levels. This implied that with proper care in design and applications, reliable measurements should be expected with his technique. Hale, L. C., Adv. Space Res., 4, 175, 1984; Maynard, N.C., in *Rocket Techniques, Handbook for MAP, Vol. 19*, 1986.

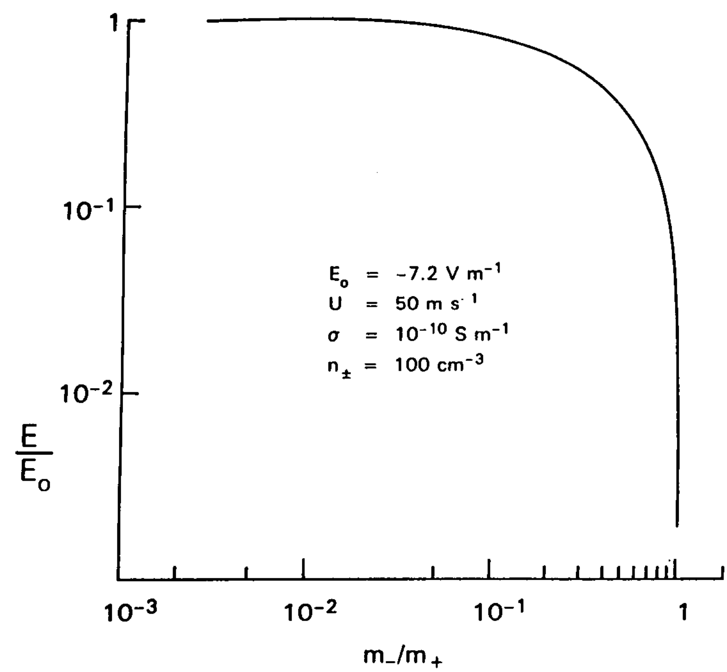

Figure 7. More recently, Curtis [1987] has produced a theory which can generate the large horizontal electric fields given the presence of horizontal winds, of charged aerosols for which the negative and positive species are of slightly different mass, and of an atmospheric electrical conductivity which is relatively low ($<10^{-10}$ S/m). The plot shows the derived relationship for changes in the electric field caused by variations in the negatively-to-positively charged aerosol mass ration, with the displayed values for number density, wind velocity, and conductivity, as boundary conditions. It is important to note that a very large electric field can be maintained until the mass ratio becomes very close to unity. If valid, this theory offers encouragement for the reality of the V/m horizontal electric field measurements. Curtis, S. A., IAGA Abstracts, CEDAR Symposium, IUGG 19th General Assembly, Vancouver, B.C., August 1987.

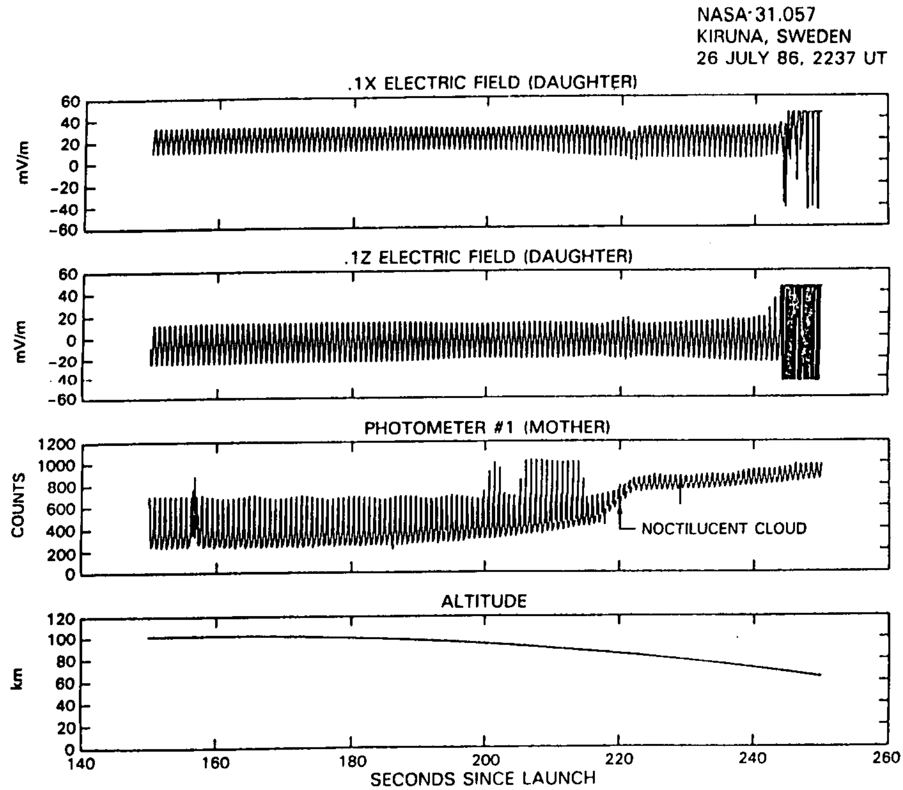

Figure 8. In July 1986, vector electric field measurements were made within a noctilucent cloud (NLC) [cf. Goldberg, 1987]. The Maynard technique was employed including deployment of the electric field array (daughter) from the main payload (mother). Displayed are two components of the electric field measured in the payload coordinate system, photometer measurements to demonstrate cloud passage [G. Witt, University of Stockholm, private communication] and altitude. The figure illustrates changes in both components of the electric field during passage through the NLC. Future measurements of this type in coordination with simultaneous measurements of winds and particulate size within NL s should help validate the Curtis theory (Figure 7). Goldberg, R. A., Proceedings of the 8th ESA Symposium on European Rocket and Balloon Experiments and Related Research, p. 159, *ESA SP-270*, 1987.

WHERE ARE MAE E FIELD STUDIES GOING?

- Further experiments to validate the large (V/m) E fields are needed.
- Tests of the theoretical explanation will be attempted in a noctilucent cloud environment.
- Expansion of the studies is required to determine the frequency, extent, and importance of the large (V/m) E fields is required.

Figure 9. Further experiments are needed to validate the large V/m electric fields. If real, they offer an important mechanism for coupling electrodynamic effects down to tropospheric altitudes, by generating electrical currents which could significantly contribute to the global electric circuit. Such contributions would in turn be modulated by incoming radiations during high latitude disturbances, which would cause conductivity enhancements that might reduce or eliminate the electric fields altogether. The importance of such effects is dependent on the frequency and extent of such fields, which must still be determined. Finally, new theoretical ideas regarding the origin of V.m fields in the mesosphere can be checked through carefully planned experiments in NLC, which contain all the essential ingredients proposed by the theory.