Direct Measurement of Vertical Potential Differences in the Lower Atmosphere

B. VONNEGUT AND R. MARKSON

Atmospheric Sciences Research Center, State University of New York at Albany Albany, New York 12222

C. B. MOORE

New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

A wire-tethered balloon system has been devised and used to measure directly the electrical potential of the atmosphere at altitudes up to 1 km above a mountain ridge in New Mexico.

It is of interest to determine the electrical potential of the atmosphere at various altitudes with respect to the earth. Measurements above several decameters become difficult with the conventional radioactive probe and electrometer apparatus [*Chalmers*, 1967] because of the inconveniently high voltages that are developed. In the past, potentials at higher levels have therefore been determined by integration of vertical potential gradient soundings made with instrumented airplanes [*Clark*, 1958] or free balloons [*Mühleisen*, 1968]. This method has the disadvantage that, because an appreciable time interval is required to make a sounding, error is introduced into the measurement. Furthermore, this method provides no information on the short-period time variations of the potential, except as they may be inferred from fluctuations in the potential gradient observed at a constant altitude.

To observe continuously the potential at a given level, we have devised an apparatus that employs a null potential balancing technique. A tethered balloon is flown at the desired elevation carrying a radiosonde electric field measuring apparatus and in close proximity a conducting sphere, which is attached to a wire that extends to the ground. If the wire is electrically connected to ground, it is evident because of the potential spanned that an electric field will be produced about the sphere. If, however, the wire is connected to a high-voltage dc power supply, as is shown in Figure 1, its potential can then be adjusted so that the electric field perturbation caused by the sphere approaches zero. Under the null condition, because no charge resides on the sphere, its potential and that of the wire are a direct measure of the potential with respect to ground at that level.

When this arrangement is used to measure large potentials, a corona current flows from the lower portion of the wire, and thus a high voltage source capable of supplying several milliamperes is required. Depending on meteorological conditions the corona space charge released from the lower portion of the wire may exert some effect on the electrical potential at the sphere, where the measurement is made. If the space charge should be carried upward by convection, this effect may be large enough to invalidate the measurements, but, if the atmosphere is stable and particularly if the wind directions aloft are different from those at lower levels, this perturbation will be small. In principle this perturbation can be made negligible by separating the sensing element from the space charge plume either vertically or horizontally with a sufficiently long wire.

During the summer of 1969 a pilot experiment to test this measurement technique was conducted at Langmuir Laboratory in the Magdalena Mountains of central New Mexico. Two tethered balloon flights were made from an exposed ridge near the laboratory 3.2 km above sea level. During each the atmospheric potential

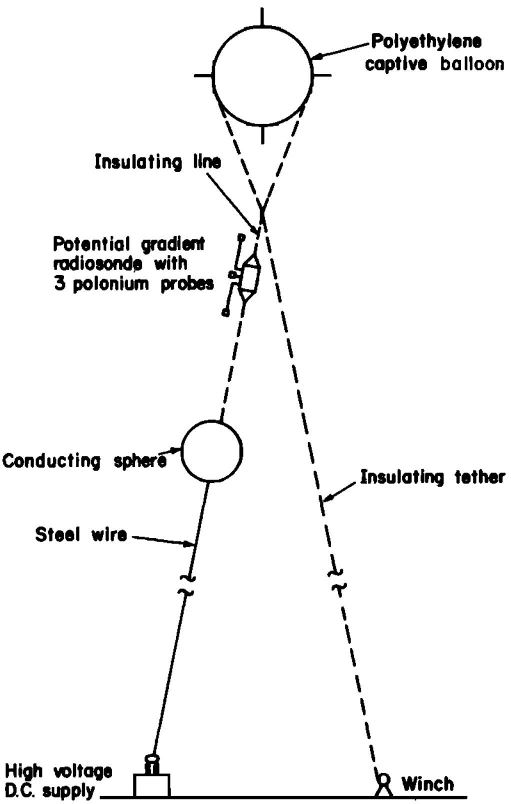

Fig. 1. Schematic of potential measuring apparatus.

was measured at three heights above the terrain. (These heights were determined from the length of the tether, which departed only slightly from the vertical.) The first flight went 600 meters above the winch; the second, 980 meters. In both soundings the electric field near the conducting sphere was detected and nulled by using a 403-MHz radiosonde modified to indicate potential gradient [*Moore et al.*, 1958].

The first flight was made on July 31, 1969, at about 1900 UT with a balloon having a volume of 85 m^3 and tethered on a 9-mm-diameter braided nylon line. The sphere, a 30-cm-diameter aquadag-coated beach ball, was suspended on a nylon monofilament 20 meters below the balloon and connected electrically to the power supply with a separate 0.5-mm-diameter stainless steel wire. The second flight, made at 1900 UT on August 14, 1969, with a 140-m^3-volume balloon tethered on a 5-mm-diameter fiberglass reinforced plastic line, was made by using a larger conducting sphere, consisting of an inflated aluminum-coated mylar balloon 1 meter in diameter. This was attached to the tether about 4 meters below the radiosonde and connected with a steel wire to the power supply. In both flights the radiosonde was arranged to sense negative gradients for 10 sec and positive gradients for 25 sec, and so, when null was achieved, the gradient of both polarities, as displayed on a recorder, stayed close to the zero reference. Thus, when no steps were apparent in the graphic record, the indicated voltage on the power supply was a direct measure of the atmospheric potential.

Figure 2 shows the data from the two soundings, which appear to be in general agreement with previous measurements reported by *Clark* [1958] and *Mühleisen* [1968]. These results indicate the feasibility of measuring large potential differences in the atmosphere by using this technique. With larger balloons capable of attaining higher altitudes and power supplies capable of delivering higher voltages it appears possible to measure nearly the entire potential difference between the earth and the electrosphere and thus to determine how it varies with time. By simultaneous measurements made at two widely separated positions it should be possible to determine horizontal potential differences that exist in the electrosphere.

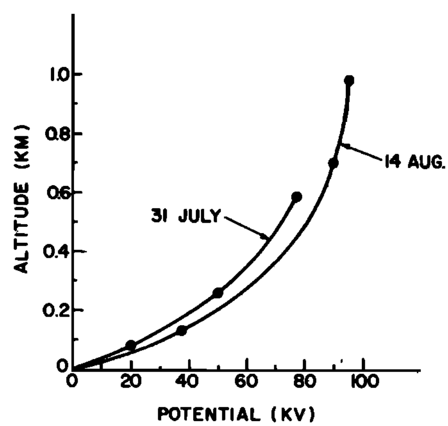

Fig. 2. Potential as function of altitude above mountain ridge near Langmuir Laboratory, New Mexico, for July 31, 1969, and August 14, 1969.

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