NOTES AND CORRESPONDENCE

Assembly and Field Testing of a Ground-Based Presence-of-Cloud Detector

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ABSTRACT

A presence-of-cloud (POC) detector has been developed for use in remote locations. The principal components of the POC detector are a moisture-sensitive resistance grid, a heater, a fan, and housing with rain shielding. Field testing at a mountain site shows that the detector functions properly when compared with observations of surface clouds or fog and meteorological parameters measured over the same time period. Although heavy, driving rain may require enlargement of the rain shield, the POC detector appears to be a rugged, low-cost alternative to existing cloud detectors.

1. Introduction

It has been shown repeatedly that clouds and fog contain high concentrations of pollutants when compared with rain or snow (e.g., Mrose 1966; Petrenchuk and Drozdova 1966; Falconer and Falconer 1980; Schemenauer 1986). Recently, there has been increasing concern that cloud water deposition may play a key role in the hypothesized decline of high elevation forests. This concern has led to the establishment of cloud sampling networks in both Canada (e.g., the Chemistry of High Elevation Fog project, Schemenauer 1986) and the United States (e.g., the Cloud Water Project, Weathers et al. 1986, and the Mountain Cloud Chemistry Project, Mohnen et al. 1986). A primary objective of these projects has been to estimate hydrologic and chemical inputs to the forest from cloud events. Difficulties in measuring the variables which influence cloud water deposition have led to uncertainties in deposition estimates. One of the most important variables, the frequency and duration of cloud events, has been difficult and expensive to estimate (Schemenauer 1986). As part of the Mountain Cloud Chemistry Project, we have developed a simple, inexpensive presence-of-cloud (POC) detector that allows accurate determination of both the frequency and duration of mountain clouds and can be used in the harsh environment of high elevation forests.

2. Materials and methods

a. Site description

The POC detector was developed within the Department of Environmental Sciences at the University of Virginia. Field testing was conducted at the Pinnacles Research Site located in the northern half of Shenandoah National Park, Virginia. The site consists of a western-facing mountain watershed (3 km^2) of mixed oak forest with instrument towers placed at the summit (1014 m above sea level), midslope (716 m above sea level) and park boundary (524 m above sea level). All towers were constructed to extend 3 m above the canopy and were equipped with meteorological instrumentation to continuously monitor wind speed and direction, relative humidity, solar radiation, temperature, precipitation, and barometric pressure. Additionally, the summit tower was equipped with a passive cloud water collector (Castillo et al. 1983) and a cloud liquid water content monitor developed by the Tennessee Valley Authority site of the Mountain Cloud Chemistry Project. Field testing of the POC detector was conducted at the summit tower.

Field tests began on 24 June 1987 and continued through the summer. Data from the POC detector were verified by comparison to observations from site personnel (present for approximately 80% of the test period) and meteorological data at the site.

b. Description of the detector

The POC detector consists of a moisture-sensitive resistance grid (patterned after commercially available leaf wetness sensors) composed of 10 interlacing fingers of gold-plated copper on a backing of 0.08 mm Mylar film (Fig. 1). The grid measures 25.4 mm by 76.2 mm, with each finger 1.5 mm wide and separated from adjoining fingers by 1.0 mm. The use of gold plating reduces the loss of sensitivity due to oxidation. Since the grid is part of a voltage divider network (Fig. 2), the voltage drop across the grid is proportional to the resistance of the grid. The resistance of the grid decreases as grid wetness increases (e.g., when impacted by a

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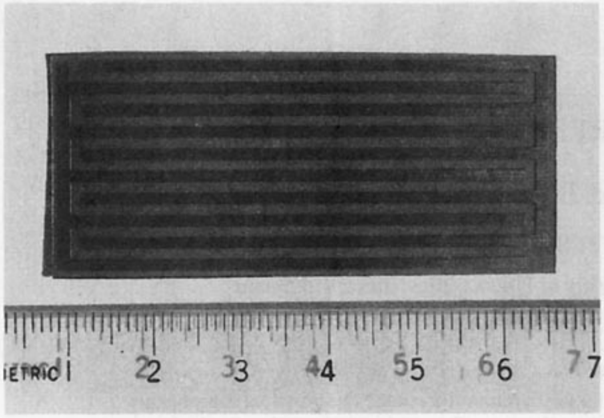

FIG. 1. Photograph of the moisture-sensitive resistance grid, showing the pattern of interlacing fingers.

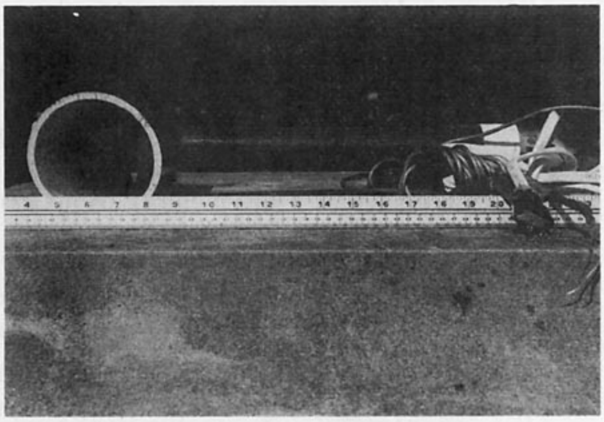

FIG. 3. Photograph of the POC detector assembly.

cloud). The divider network is excited, and the resulting voltage drop across the grid recorded.

The grid is mounted with double sided tape to the side of a 38 mm i.d. boom which passes at a right angle through a cylindrical rain shield (101 mm i.d., by 305 mm length, Fig. 3). A 3 W ac heater inside the boom and directly behind the grid prevents condensation on the sensor except when a cloud is present. This heater, combined with the vertical orientation of the grid fingers, also facilitates drying after a cloud event.

The POC detector was mounted near the top of the canopy on the summit instrument tower. The body of the assembly was oriented parallel to the ground with the inlet pointing in the direction of predominant winds (the topography of the watershed results in the frequent occurrence of upslope or downslope winds). To enhance detection of clouds in low wind speeds, ambient air was pulled through the rain shield at approximately 5 m s^{-1} by an ac fan mounted behind the grid. All signal lines were run through lightning protection and into an instrument shelter at the base of the tower where a Campbell 21XL Datalogger was housed. The Datalogger excited the divider network every 5 seconds, and the resulting voltage drop was recorded. Data from the POC detector and all meteorological instruments were recorded on magnetic tape and retrieved weekly for analysis. The resistance grid was cleaned weekly using denatured alcohol and a cotton swab to remove surface contaminants.

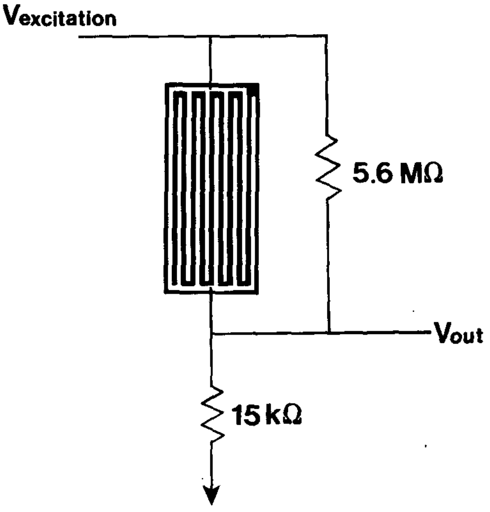

FIG. 2. Schematic of the voltage divider network. All resistors are 0.25 watt, 10% carbon resistors. Note the position of the resistance grid within the divider network.

To simplify analysis, a voltage threshold (indicating saturation of the grid) was chosen as the transition from no-cloud to cloud conditions. A software flag was set using this voltage to indicate the presence ("1") or absence ("0") of a cloud. The voltage threshold was refined at the midpoint of field testing by reprogramming the Datalogger during a cloud event to reflect Mountain Cloud Chemistry Project guidelines defining the presence of a cloud (<1 km surface visibility).

3. Results and discussion

The test period ran for twelve weeks, during which a total of nineteen cloud events were indicated by the detector. Eighteen events were confirmed as correct by correlation with related meteorological parameters. Personnel were available at the research site to verify thirteen events by direct visual observation. One "event" during heavy, blowing rainfall was incorrectly recorded as a cloud because inadequate rain shielding on the detector allowed water to reach the sensing grid. One cloud indicated by meteorological parameters was not detected due to a power failure on the tower.

The combination of low daytime solar radiation readings with relative humidities in excess of 95% (characterized by saturation of the relative humidity probe) is often used to infer the presence of clouds. Figure 4 shows a representative 20-day period during

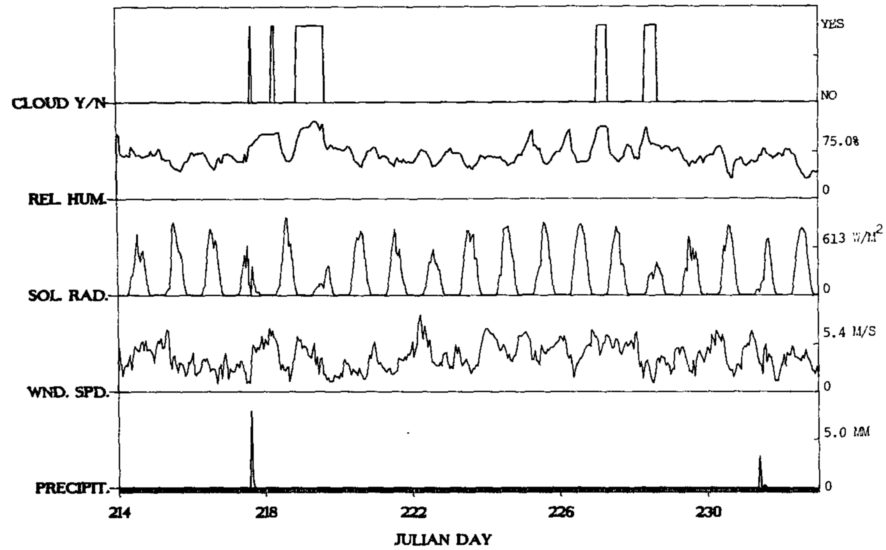

FIG. 4. Twenty-day time series of precipitation, wind speed, solar radiation, relative humidity, and POC detector signal taken during the test period.

which five clouds with durations ranging from 1 to 18 hours were detected. A total of 36 hours of cloud occurrence was recorded during this portion of the test period. The detector's indication of cloud presence is supported by the high, flattened RH curve and the reduced level of solar radiation (e.g., day 219). Further confirmation was provided by site personnel.

The POC detector operated correctly throughout a wide range of cloud conditions. While clouds with high liquid water contents (>0.5 g m^{-3}) accompanied by moderate wind speeds (>5 m s^{-1}) are relatively easy to detect, clouds with low liquid water contents (<0.2 g m^{-3}) accompanied by low wind speeds (<5 m s^{-1}) are more difficult to detect. Conditions of low liquid water content and low wind speed were observed during events on Julian day 218 and 228, during which the detector responded correctly (Fig. 4).

Initial testing indicates that the POC detector can provide a reliable indicator of cloud occurrence. The detector is designed to withstand the harsh conditions encountered on mountain tops and has even survived several lightning strikes to the instrument tower. A POC detector has been in continuous operation at the Pinnacles Research Site from June 1987 through December 1987. During this period, the detector failed to function properly only when power to the instrument tower was lost and during one heavy rime ice event which damaged the ac fan. The use of impedance protected ac fans has prevented subsequent failure of the fan due to rime ice. The POC detector could be modified for use with a battery backup system if uninterrupted data were essential.

To prevent false readings due to heavy rainfall accompanied by high winds, it may be desirable to lengthen the rain shield. Since the threshold of the POC detector is adjustable, the sensitivity of the POC detector can be easily modified for individual needs. The simplicity, ruggedness, and low cost ($35) of this detector make it an attractive alternative to detectors presently available.

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