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Microorganisms of the Upper Atmosphere

V. Relationship Between Frontal Activity and the Micropopulation at Altitude

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ABSTRACT

FULTON, JOHN D. (U.S. Air Force School of Aerospace Medicine, Brooks Air Force Base, Tex.). Microorganisms of the upper atmosphere. V. Relationship between frontal activity and the micropopulation at altitude. Appl. Microbiol. **14**:245–250. 1966.—The relationship between frontal activity and the micropopulation of the atmosphere at altitude is described. It is shown that certain of the meteorological events associated with frontal activity quantitatively modify the micropopulation of the atmosphere. Precipitation associated with frontal passage reduces the micropopulation at altitude, whereas frontal activity with high levels of associated surface and atmospheric turbulence results in great increases in micropopulations of the upper atmosphere—particularly in those situations where surface conditions are conducive to the development of dust.

Most of the available information concerning the relationship between meteorological events and the micropopulation of the atmosphere has been obtained from surface and near-surface studies (2). Very little is known concerning the relationship at higher altitudes. It is the purpose of this study to determine the influence of frontal activity on the micropopulation of the atmosphere at altitude.

MATERIALS AND METHODS

Sampling instrumentation, techniques, and microbiological processing utilized in this study have been reported (1, 3).

The sampling location utilized in this study was the area surrounding Junction, a small community in south central Texas approximately 100 air miles from San Antonio. The climate is semi-arid, and the surrounding terrain consists of low rugged hills sparsely covered by scrub trees and brush. Agricultural activities are limited, with grazing the major activity. The mean altitude is approximately 500 meters (1,800 ft). Junction was selected because the area is subject to frequent cold-front passages, moving from a northerly direction during the winter season. In this area, dust activity is often associated with fast-moving fronts, and the transient air masses are normally shallow, seldom extending above 3,000 meters (10,000 ft). Under stable meteorological conditions, the micropopulation at altitude is relatively low during the winter months.

In this study, three altitudes were sampled simultaneously, with the aircraft in a vertical stack formation. The altitudes sampled were generally 365, 1,280, and 2,500 meters (1,200, 4,200, and 8,200 ft) above terrain (specific altitudes are indicated on each figure). Winter background micropopulations were established by a series of samplings in the area. Each of the background studies was accomplished under different meteorological conditions as regards wind direction, type of air mass, temperature, and other factors. The background studies had but one meteorological factor in common—absence of any frontal activity. In both background and frontal studies, 20-min sampling tracks, with Junction as the midpoint, were flown. Background tracks were crosswind, and frontal tracks were perpendicular to the general direction of frontal movement.

Experimental samples were obtained during and after frontal passage. Because of cloud cover, reduced visibility, and turbulence normally accompanying the leading edge of a cold front in this area, sampling during the early stages of frontal passage was not always possible. Sampling was initiated as soon as possible after frontal passage.

RESULTS

The average winter nonfrontal background micropopulations found in a series of five studies were 151 (SE ±20; n = 58), 61 (SE ±8; n = 57), and 38 (SE ±5; n = 50) at the altitudes of 365 (low), 1,280 (middle), and 2,500 (high) meters.

The effectiveness of precipitation associated with frontal activity and moist surface conditions in modifying the micropopulation at altitude is shown in Fig. 1. Both of the studies were accomplished under meteorological conditions similar in most respects, with the presence or absence of

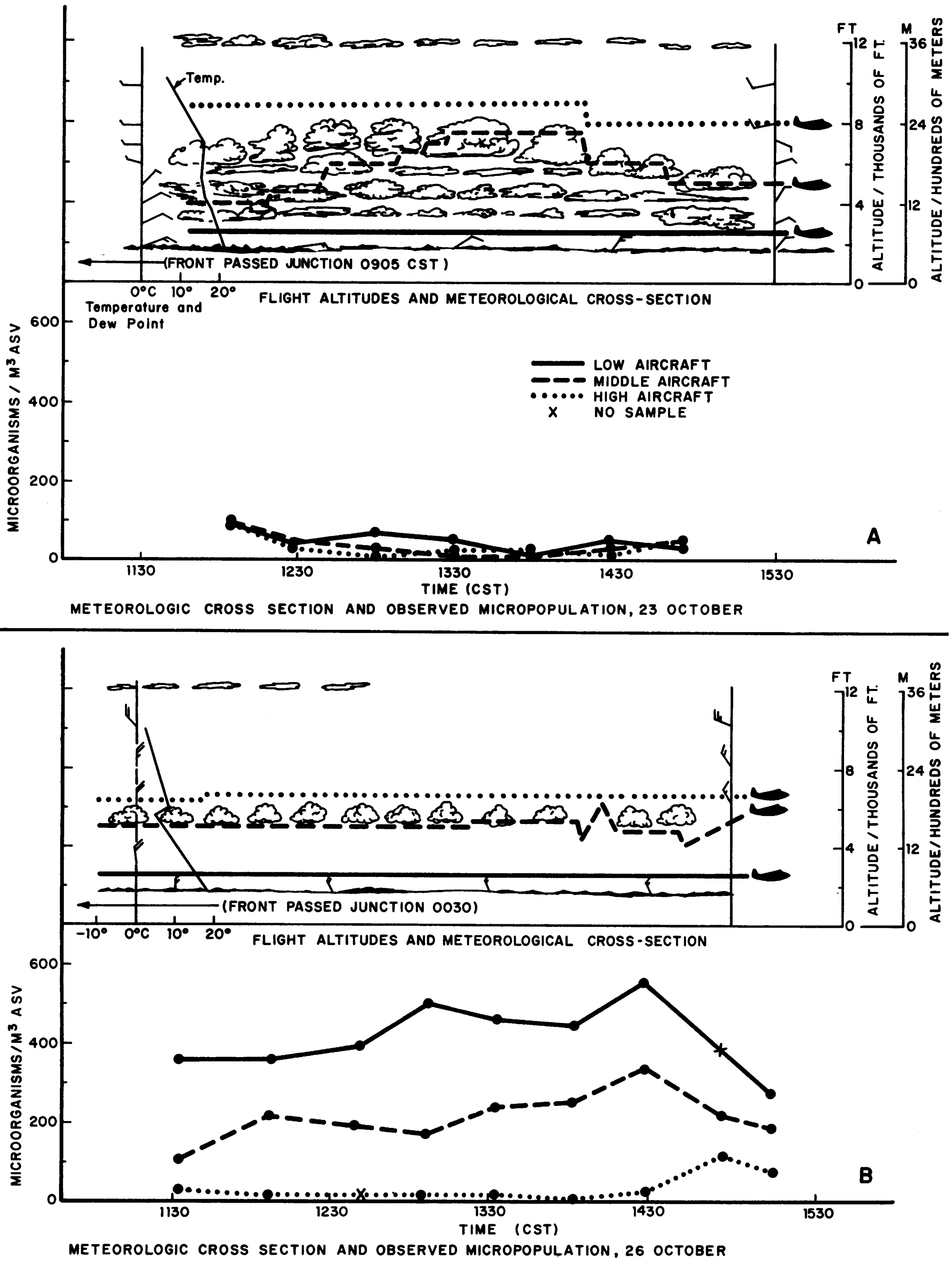

FIG. 1. *Effect of frontal activity accompanied by rain and moist surface conditions. (A) Rain accompanying frontal passage. (B) No rain but ground moist from the rain accompanying the front in A. The upper portion of each section is a cross-sectional diagram of the meteorological conditions at the time of sampling. Wind direction and velocity are indicated by the barbed arrows, with north at the top of the figure. Each long and short barb represents a wind speed of 10 and 5 knots, respectively. Temperature lapse rate diagrams are included in each cross-section to show the location of temperature inversion zones. Flight altitudes are included in the cross-section diagram. The true flight courses were perpendicular to the cross-sectional diagram and not parallel as indicated. Microbiological data are presented in the lower portion of each section and include: ordinate, numbers of microorganisms per cubic meter of air space volume (ASV); abscissa, sampling time (24-hr clock). Times pertain to both microbiological and cross-sectional meteorological data. The micropopulations are plotted as dots with the dots connected by lines coded for each altitude.*

precipitation accompanying the front being the major variable. Air masses involved were moderate Pacific Polar cold fronts moving into the area from a northerly direction. Sampling was initiated 3 (Fig. 1A) and 11 hr (Fig. 1B) after passage of the leading edge of a front. The front depicted in Fig. 1A was accompanied by steady light precipitation, and, in addition, the frontal air mass had approximately a 500-mile trajectory through a precipitation area prior to its arrival. The lower-than-normal background micropopulation ($P = <0.001$) found at the low and middle altitudes after passage of the wet front (Fig. 1A) was unquestionably the result of washout of suspended particulate matter; in addition, the moist surface conditions that prevailed in the widespread area over which the air mass passed reduced introduction of microorganisms into the atmosphere. No precipitation accompanied the front shown in Fig. 1B. The ground surface, although drying from the precipitation accompanying the earlier front, remained sufficiently moist to reduce dust formation and concurrent dissemination of large numbers of microorganisms into the atmosphere. Nevertheless, the micropopulations found at the low and middle altitudes were well above background levels ($P = <0.001$).

The data from a study in which frontal activity was accompanied by a moderate dust storm are presented in Fig. 2. The dust moved into the area with a fast-moving Pacific Polar cold front and was caused, at least in part, by the surface turbulence associated with frontal passage. The initial sample (Fig. 2A) at the low altitude was taken within the leading edge of the front and dust zone, and all subsequent samples were within the dust zone. This accounts for the extremely large micropopulations found. The leading edge of the front reached the middle altitude approximately 2 hr after start of sampling. Immediately upon penetration of the frontal and dust zone boundary, a considerable increase in micropopulation was observed. Since the front and dust zones did not reach the high altitude, the micropopulation remained well within normal background levels. The postfrontal micropopulation 24 hr after the passage of the front is shown in Fig. 2B. By this time the dust had subsided and a relatively stable meteorological pattern had developed; the micropopulations at the low and middle altitudes, although somewhat elevated, were approaching background levels. The inversion zone, located slightly above the high sampling altitude, contributed to the higher-than-background micropopulations at this altitude.

Micropopulations at the low and middle altitudes in Fig. 2A show a relative stability which is indicative of a degree of micropopulation homogeneity within the frontal air mass. A more erratic pattern was found in the frontal study illustrated in Fig. 3. Sampling was started approximately 3 hr after passage of a fast-moving Polar Pacific cold front. High-velocity winds, turbulence, and heavy dust, through the middle sampling altitude, were associated with frontal passage. The dust cloud subsided approximately 4 hr after start of sampling, with light dust in evidence at the surface through the low sampling altitude after this time. Figure 3A shows the high and erratic micropopulations found, at all altitudes, during this study. The erratic pattern evidences the existence of strong air current swirls and eddies within the atmosphere under certain postfrontal conditions. It is of importance to note the reduction in micropopulation at the middle and high altitudes following the dissipation of the dust; the micropopulation at the low altitude, however, remained high and erratic throughout the entire sampling period. The area was resampled (Fig. 3B) starting approximately 3 hr after completion of the earlier mission. Only traces of dust remained in the near-surface layers of the atmosphere, and micropopulations were approaching background levels. Attention is called to the three peaks in micropopulations observed. At approximately 1400 hr, a single high micropopulation was found at the low altitude. This peak was reflected at the middle and high altitudes 20 and 40 min later. The most likely explanation to account for this observation is that the peaks were the consequence of micrometeorological disturbances such as a "dust devil" or a thermal current which transported the microorganisms within a limited parcel of air to altitude, appearing first at the low altitude and in sequence at the middle and high altitudes.

The distribution of bacteria and fungi was determined. Background microorganisms at the low altitude were about equally divided between bacteria (43%) and fungi (57%); at the middle and high altitude, bacteria comprised 70 and 90%, respectively. In all cases, during frontal activity, where dust was present at the sampling altitude, bacteria exceeded the fungi. When the terrain surface was moist, fungi exceeded bacteria.

Microorganisms collected were identified as to genus. Although, in both background and frontal situations, the numbers of a specific genus of bacteria or fungi collected at the various altitudes and times varied, no definite pattern was apparent. The average distribution of each bacterial genus was as follows: *Micrococcus*, 34%; *Bacillus*, 30%; *Streptomyces*, 19%; *Bacterium*, 8%; *Corynebacterium*, 6%; unidentified, 3%. The predominant fungi collected were *Hormodendron* (30%),

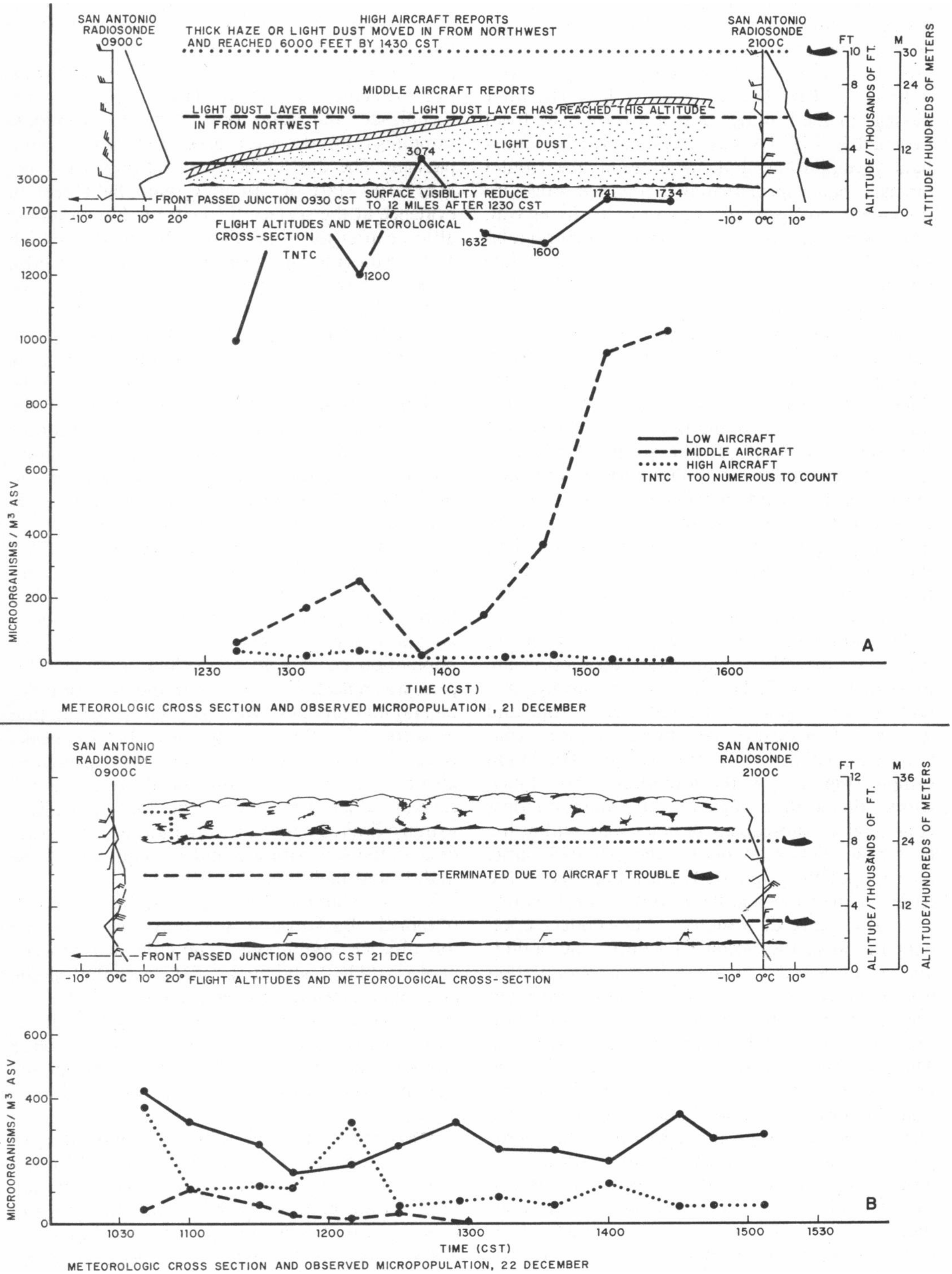

FIG. 2. *Effect of frontal activity with accompanying dust. (A) Front accompanied by dust activity; (B) micropopulation 24 hr after passage of the front in A. Figure interpretation as in Fig. 1.*

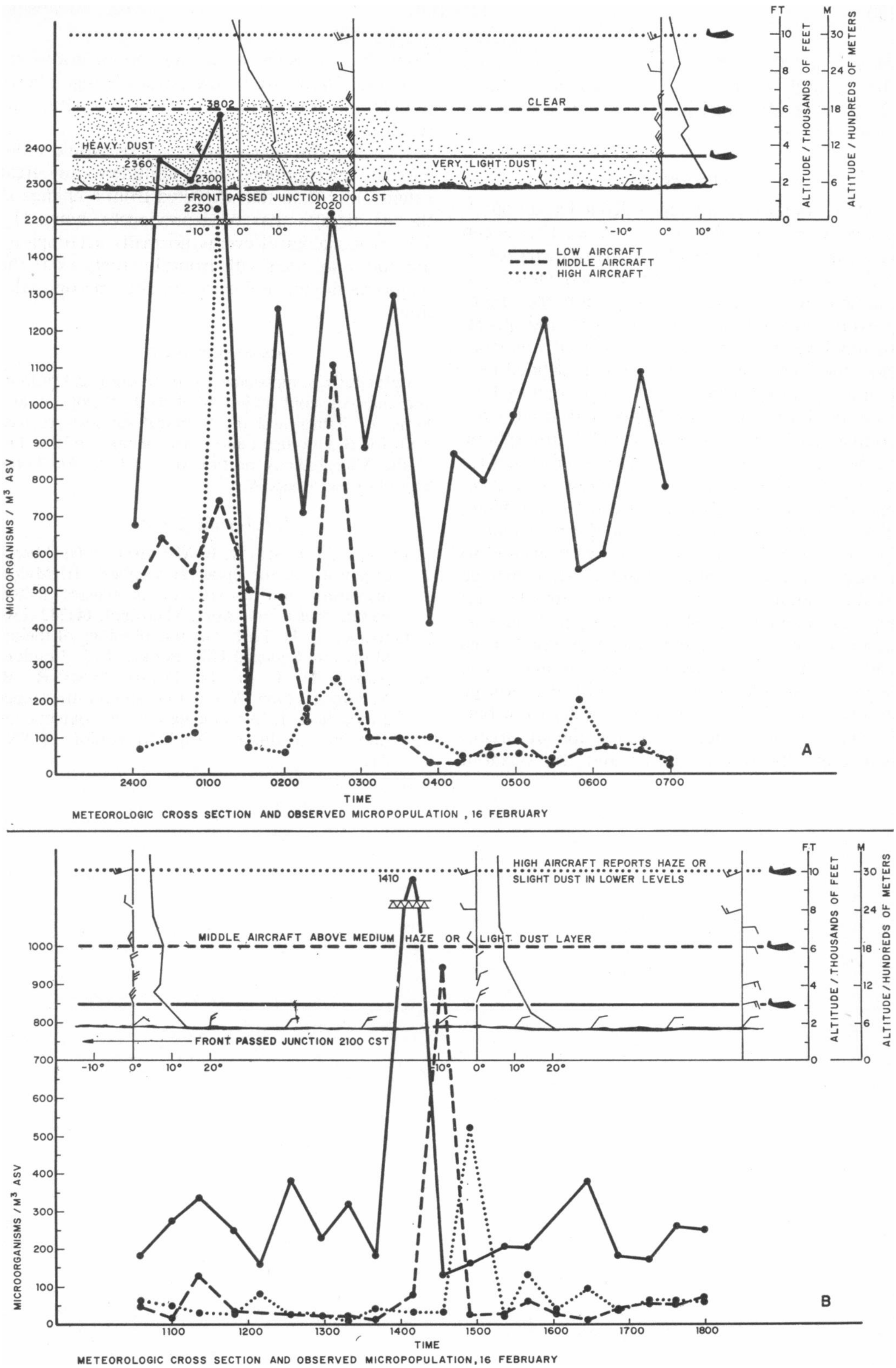

FIG. 3. *Variability in micropopulation during frontal activity accompanied by heavy dust. (A) Immediately after frontal passage; (B) 4 hr after termination of study in A. Figure interpretation as in Fig. 1.*

Alternaria (20%), *Penicillium* (14%), *Aspergillus* (10%), and yeast (3%). The remaining fungi (26%) were identified in 26 different genera, all typical soil forms.

Discussion

Meteorologically, a front is defined as a boundary between two different air masses. Fronts can be subdivided in terms of the many meteorological elements with which they are associated; for example, temperature, wind direction and speed, pressure, precipitation, air mass type, and others. In this investigation, one type of front was studied—the cold front. A cold front is defined as a boundary along which warm air is replaced by cold air. Fast-moving cold fronts are usually accompanied by increased surface and atmospheric turbulence. Under dry conditions, the surface turbulence increases the dissemination of surface-originating microorganisms into the atmosphere, and the greater turbulence within the atmosphere, in turn, tends to hold the microorganisms and to transport them to higher altitudes. After passage of the frontal zone, the turbulence subsides and the micropopulation of the atmosphere returns, in a relatively short time, to the levels compatible with the meteorology of the new air mass. The degree of turbulence associated with the passage of a wet front is similar to that of a dry front but, because of the reduced dissemination of organisms from the moist surface and the washout from the atmosphere, the micropopulations remain low. In this study, the extremely high micropopulations observed were unquestionably the result of dust activity.

It is doubtful that a front, per se, would influence the micropopulation at altitude to any great extent other than that expected from a change in the air mass, as has been previously shown (1). The meteorological events normally accompanying and associated with frontal activity exert the major modifying influence on the micropopulation.

Acknowledgments

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