Climatology of Superadiabatic Conditions for a Rural Area[1]

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ABSTRACT

Temperature measurements taken over a 6-year period from a 32 m tower are used to study the climatology of low-level superadiabatic conditions in a rural area. Plots of monthly distributions of event commencement times and durations display a high degree of symmetry compared to the distributions for inversions previously published. This climatology can be used to better identify periods when spores, pollens, insects, smoke or agricultural chemicals introduced at the surface will quickly become available for long-range transport by the upper level winds.

1. Introduction

In a previous report (Takle *et al.*, 1976, hereinafter referred to as TSV) analyses were presented of the characteristics of nocturnal, ground-based temperature inversions in rural areas. Plots of the percentage of monthly total number of inversions as functions of commencement time and duration revealed winter and spring inversions to begin near sunset and to persist for periods only slightly longer than the sunset-to-sunrise time. By contrast, summer and fall inversions tend to begin before sunset and persist 20–30% longer than the sunset-to-sunrise period.

The onset of surface heating after sunrise leads to evaporation of dew and erosion of the surface-based inversion. Rapid changes above the surface layer also occur; Thorpe and Guymer (1977) report an abrupt destruction of the nocturnal jet very near sunrise. The early growth of the superdiabatic zone can lead to surface fumigation as the convective region extends into a pollutant-enriched layer aloft (Wolff *et al.*, 1979). The transport of agricultural chemicals applied during this transition period can change markedly as the surface layer changes from highly stable to moderately unstable.

This note presents analyses of the climatological characteristics of superadiabatic conditions in a rural area and compares their climatological characteristics with those of inversions. A brief analysis also is presented of the evolution of the lapse rate during the morning stability-transition period.

2. Data and results

The results presented were derived from the same data set described in TSV. Briefly, the data set consists of hourly measurements of ΔT between 2 and 32 m on a tower located in a primarily rural area near Ames, Iowa, taken over a period of almost six years. See TSV for further details.

a. Comparison of distributions of superadiabatic events with inversions

During the nearly six years of tower operation, 2828 superadiabatic periods were recorded (compared with 2645 inversions during the same period). For comparison between months, the data were corrected for nonuniform distribution of equipment downtime. Figs. 1 and 2 give the mean number of occurrences per day of superadiabatic events and inversions, respectively. Occurrences of long (>3 h) events also are shown. Although the scatter is large for total events, there is a suggestion that both inversions and superadiabatic events occur more frequently in early summer and less frequently during cool months. For the long-lived events, inversions show more seasonal dependence than do superadiabatic events. These plots reveal that during June through October (period when a vegetative cover is present) long-lived inversions occur with greater frequency than do superadiabatic conditions, whereas during November through February, there is a slight tendency for superadiabatic events to be more frequent.

Fig. 3–4 give plots of superadiabatic data on graphs previously reported in TSV on characteristics of inversions. Thus, Fig. 3 gives a plot of the percentage

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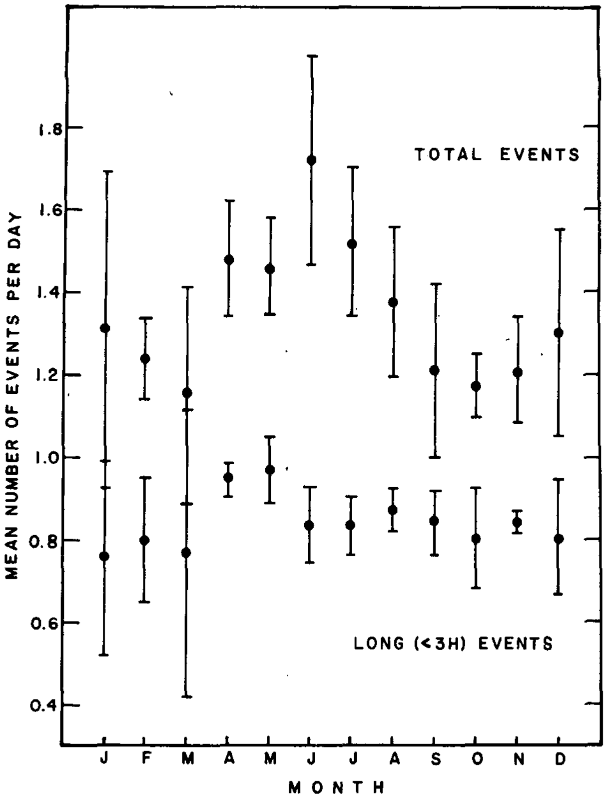

FIG. 1. Frequency of occurrence by month of superadiabatic conditions.

of monthly total superadiabatic occurrences as a function of commencement time for each hour of the day for each month, with corresponding data for inversions from TSV. Each monthly distribution of superadiabatic events in Fig. 3 is almost a mirror image about 1300 LST of the distribution of inversion events. Solar azimuth at Ames equals 180° between 1210 and 1230 LST.

The period between superadiabatic commencement time and inversion commencement time represents the period during the diurnal cycle in which strong coupling exists between the surface layer and upper levels. Pollens, spores, wind-borne insects, smoke, and agricultural chemicals present in the atmospheric surface layer during this period will be mixed through a relatively deep layer and will be available for long-range transport by the flow aloft.

In the agriculturally intensive midwest of the United States, the direction of this transport can be approximated by the direction of the 850 mb flow. At times other than this period, surface flow will be more strongly controlled by local orography; hence, synoptic-scale winds cannot be used to predict the transport of natural or anthropogenic materials introduced after the onset of the nocturnal inversion and before the establishment of significant superadiabatic conditions the following day. Fig. 3 provides statistics for approximating periods when synoptic-scale and local-scale steering can be expected for materials introduced at the surface.

Duration of events, shown in Fig. 4, reveals significant differences between inversions and superadiabatic events. Inversions, in general, seem to last longer in all months and, for all months except January, have a dominant peak in the monthly distribution that more or less follows the length of the nocturnal period. The peak of the monthly distribution of superadiabatic events, on the other hand, generally follows the daylength period from September through March, but then loses its identity from April through August. Long continuous unstable periods evidently are replaced by shorter periods separated by an hour or two of neutral or stable conditions. The surface layer seems reluctant to remain superadiabatic for more than 10 h at this location.

A comparison of Fig. 3 and Fig. 4 with the tabular results of Moses and Bogner (1967) for a 144 ft tower at Argonne National Laboratory shows the Ames data to have the same seasonal dependence of superadiabatic onset time and duration, the only consistent difference being a lag of ~1 h in the onset time at Ames, due in part to the 23 min later sunrise at Ames.

b. A climatology of the morning transition for cloud-free days

The morning transition on clear days from stable laminar flow to surface-based convective flow causes

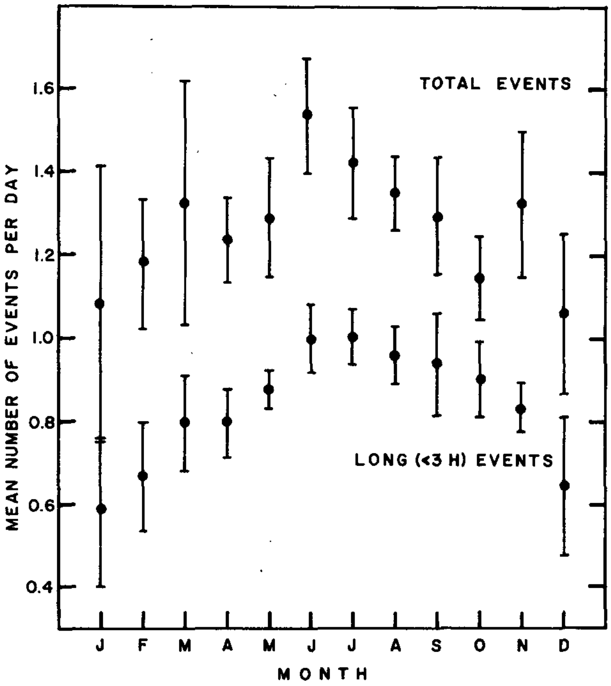

FIG. 2. Frequency of occurrence by month of inversion conditions.

rapid and significant changes in the dynamics and pollutant dispersing properties of the lower atmosphere. To study the seasonal dependence of this transition, we constructed a data set of all clear mornings (0000–1200 LST) in January, April, July and October during the period of the record. Shortwave energy flux incident at the surface is proportional to the sine of the solar altitude, so I have plotted in Fig. 5 the observed temperature difference as a function of the sine of the altitude. January mornings become superadiabatic most quickly, July mornings most slowly, with April and October between these extremes. The ordering results from 1) a larger inversion strength at sunrise (especially July) requiring more insolation to dissipate, and 2) evaporation of dew and surface moisture being more significant in July and April than in October and January. During the period of intense agricultural activity (April through October), the atmosphere on clear days requires 1½–2 h beyond sunrise to become unstable through a 32 m depth (as compared to about 1 h in winter). Fig. 3 shows that somewhat more time is required, particularly in late summer, for superadiabatic conditions to become established when all sky conditions are considered. This has obvious implications for agricultural practices (e.g., spraying, burning, dusting) whose beneficial or detrimental effects depend on turbulent transport from the source area.

The model results of Experiment II of Orlanski *et al.* (1974) for the morning transition show qualitative agreement with the results of Fig. 5, although detailed comparison is not possible because of the differences in height intervals and the absence of moisture in the model. However, their results for Experiment I (which uses sinusoidal rather than constant nocturnal surface cooling as in II) differ substantially from Fig. 5, particularly in the amount of time necessary to accomplish the transition from inversion to super-adiabatic. The importance of proper parameterization of surface conditions is thereby demonstrated.

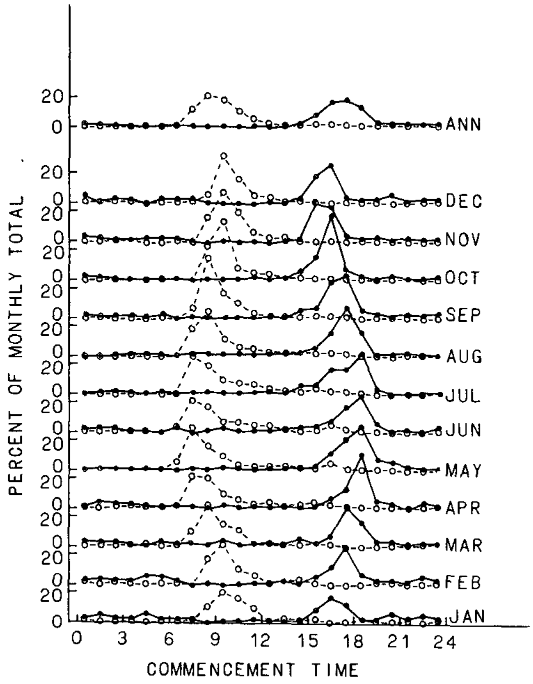

FIG. 3. Monthly distribution of commencement times of superadiabatic conditions (open circles) and inversions (solid circles).

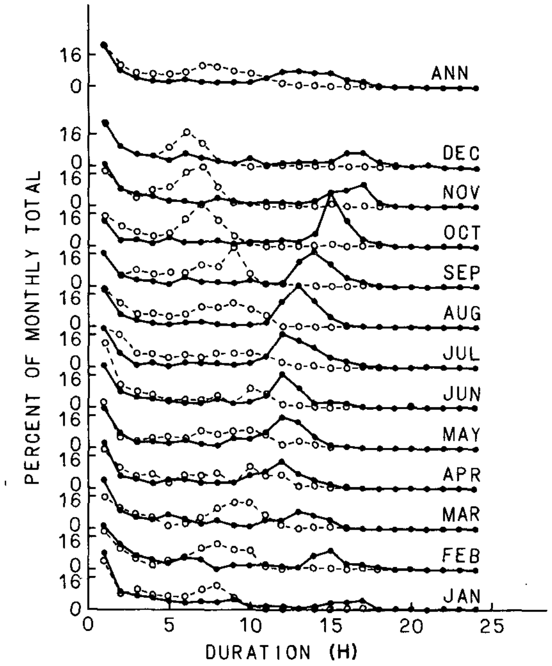

FIG. 4. Monthly distributions of durations of superadiabatic conditions (open circles) and inversions (solid circles).

3. Summary

Analysis of superadiabatic events for a rural area and comparison of their climatology with that of inversions reveals some interesting seasonal effects and symmetries. The mirror imaging of some of the distributions was quite unexpected. Statistical properties of the morning transition from stable to unstable conditions have potential use in planning operations whose effects or effectiveness depend on the onset of turbulent mixing in the lower atmosphere. These statistics also provide information on movement of pathogens or insects whose movement may originate daily from surface source regions.

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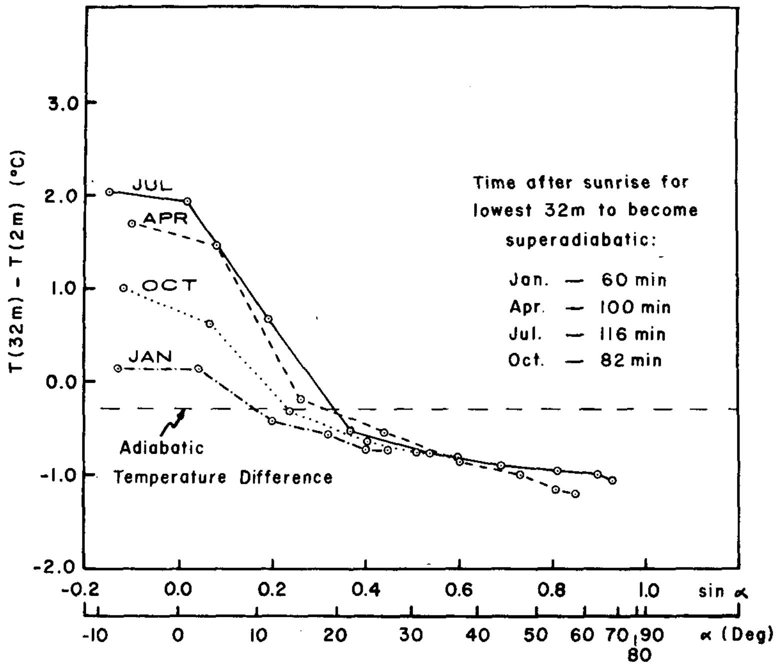

FIG. 5. 30 m temperature difference as a function of solar altitude for clear days during various months.

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