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THE NEAR SURFACE TEMPERATURE FIELD IN A BASIN DURING NOCTURNAL DRAINAGE FLOW

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1. INTRODUCTION

Analysis of the nighttime near-surface air temperatures in a complex basin reveals some interesting behavior. Data collected by 27 NCAR PAM stations[1] during the 1980 DOE ASCOT[2] experiments (Dickerson, 1981) in the Anderson Creek valley of northern California were used in this study. The PAM stations collected wind speed, wind direction, pressure, temperature, and humidity data at 1-minute intervals from sites throughout the basin from its floor to ridgetop. Half-hour average temperature and pressure data were used to examine empirically the time-dependent behavior of the near-surface (2 m) temperature at each site during the nighttime period (1900–0500 PST). During this time period noctural drainage winds usually existed throughout the basin.

2. EMPIRICAL ANALYSIS

Attempts were made to fit the nighttime temperature patterns to a power series in time using wind speed, wind direction, slope of terrain, and pressure as parameters. This analysis led to the conclusion that the station pressure was the only significant parameter for this data set. Since the pressure at a given site varies only slightly during the night, it is really reflecting the effect of the station's altitude. The fact that the other parameters contribute only marginally to improvements in the calculated temperature agrees with the findings of McCutchan (1979). Further analysis of the power series showed that the change in temperature with time at all stations could reasonably be described by the simple relationship

$$T = T_a \exp[-A(P-P^*)t] \qquad (1)$$

where T_a is the average temperature at the station from 1900 to 0500 PST, P is the half-hour mean pressure, and t is the time measured in hours from midnight with times before midnight being negative. The time at the end of each half-hour averaging period is taken as the time for that measurement. A and P* are fitting parameters and vary from night to night. Table I gives the values of these parameters for each experimental night. The temperature at any given station and time depends on the local pressure, which is a measure of the effective elevation of that station.

TABLE I

EMPIRICALLY DERIVED VALUES OF THE PARAMETERS A AND P* IN EQ. (1) FOR EACH EXPERIMENTAL NIGHT

Experimental Night	Date (Sept.)	A $(mb\ h)^{-1}$	P* (mb)
1	11-12	0.0661	908
2	15-16	0.0478	912
3	18-19	0.0534	9'1
4	19-20	0.0492	895
5	24-25	0.0387	905

According to Eq. (1), which is a good approximation to the experimental data, the average temperature, T_a, for the period 1900 to 0500 PST must occur at midnight (t = 0) at each station each night. Also from (1) the time rate of change of temperature at a station is given by

$$dT/dt = -A(P-P^*)T \qquad (2)$$

From Eq. (2) it can be seen that when $P > P^*$, $dT/dt < 0$, and the cooling rate is greater at lower elevations. When $P < P^*$ the temperature increases throughout the night. Since, as stated before, the pressure variations during the night at a single station are small, this really implies that there is a critical elevation each night above which the near surface temperatures increase with time and below which they decrease.

3. SOME TYPICAL DATA

Four PAM stations positioned approximately along a line from the basin outflow to the ridgetop were chosen to illustrate the behavior indicated by Eq. (2). Figure 1 shows the location of each of these stations on a generalized cross section of the basin, running from the ridge to the area of outflow. These stations represent conditions on a ridge (PAM 4)[1], on a side slope (PAM 14), in the lower part of the basin (PAM 20), and in the outflow of the basin (PAM 24).

[1] National Center for Atmospheric Research's Portable Automated Meteorological stations

[2] Department of Energy's Atmospheric Studies in Complex Terrain program

[1] NCAR station identification

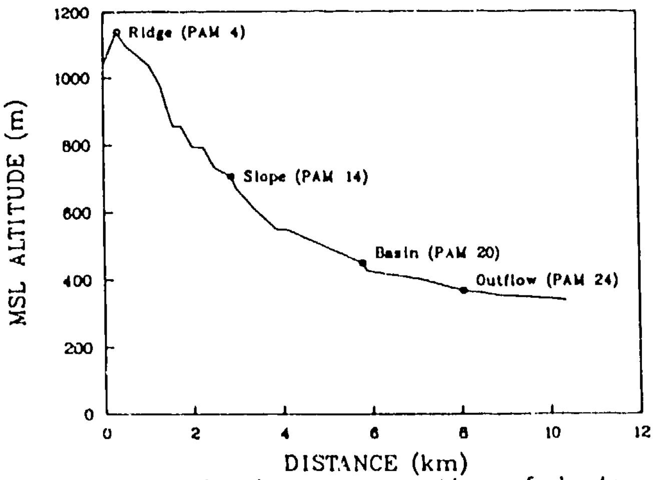
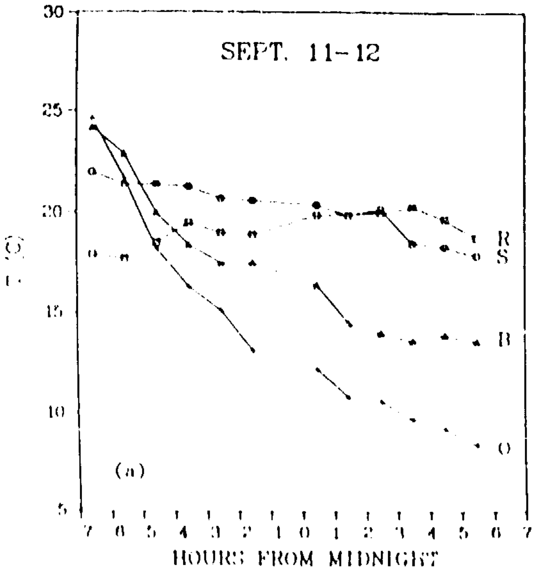
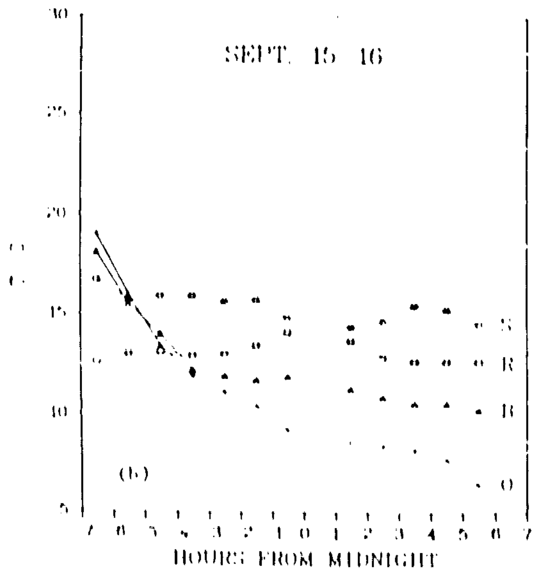
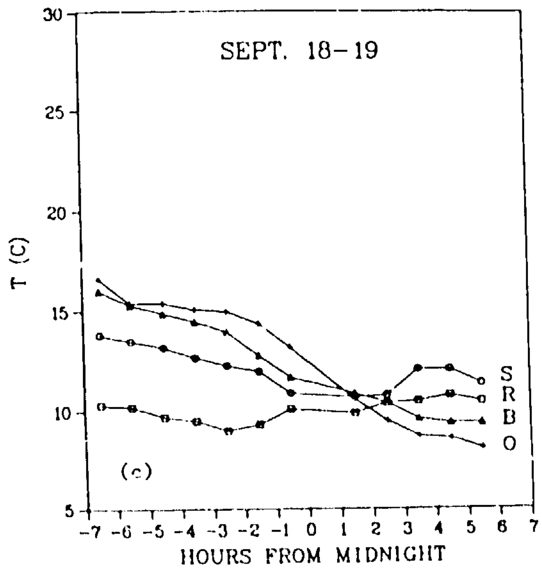


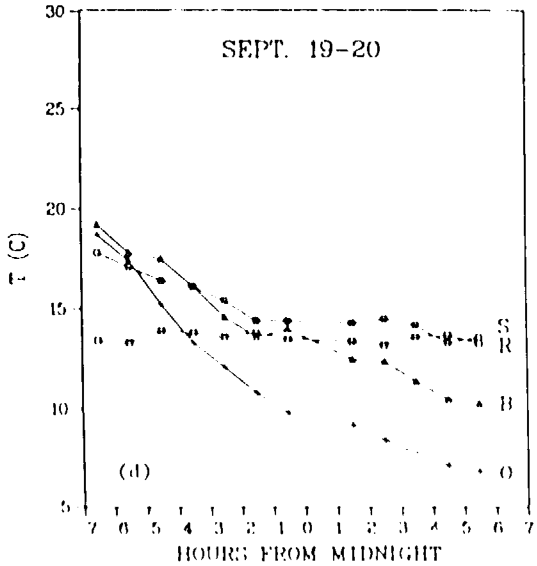
Fig. 1. Generalized cross section of basin showing locations of selected PAM stations.

Figures 2a-e show the nighttime temperature trends at each of the four stations for the five experimental nights of the 1980 ASCOT study. All nights had similar synoptic conditions with the









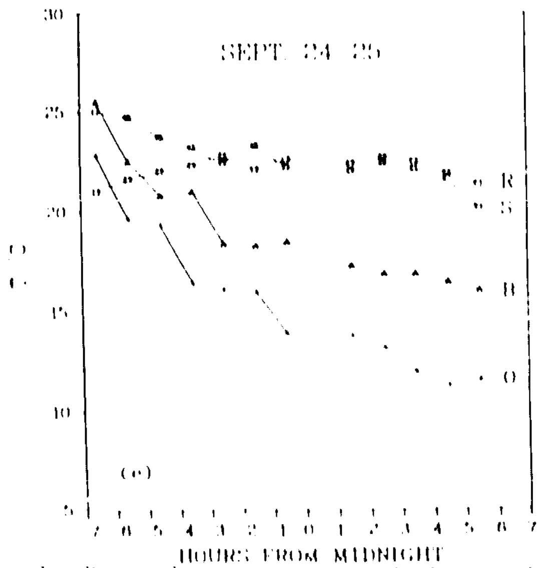


Fig. 2. Nocturnal temperature variations at four locations in the basin for the five (a-e) experimental nights during the 1980 ASCOT study. The curves are identified by: R(ridge), S(slope), B(basin), O(outflow).

exception of the night of September 18-19 on which strong synoptic winds existed near the ground and drainage winds were weak. The ridge station pressure was below or near the critical pressure P^* given in Table I on all five nights, while the other stations were all above P^*.

In all cases the ridge temperature either increased slightly or remained relatively constant for most of the night. Some cooling trends were observed in the early morning, but never did the morning temperature on the ridge fall below the value it started with the previous evening. The slope station shows a gradual cooling throughout the night with a couple of early morning warming events. However, the morning temperature on the slope was always lower than the previous evening. The basin station cools more rapidly than the slope and the outflow station even more so. The night of September 11-12 (Fig. 2a) best illustrates these phenomena. A smaller separation in temperatures is observered on the night of September 18-19 (Fig. 2c), but the general trends can still be seen in the data. With the exception of the third night, the early morning temperature differences between the outflow, basin, and slope stations averaged 4 C^o. The slope and ridge stations had nearly equal early morning temperatures (0.5 to 2 C^o difference). The ridge was cooler than the slope on three out of the five nights. The early morning temperature difference between the ridge and the basin ranged from 6 to 10 C^o, except on night three when it was only 2.4 C^o.

4. SUMMARY AND CONCLUSIONS

An empirical analysis of data from 27 surface meteorological stations in a complex basin indicates that the near surface nighttime temperature patterns can be approximated by Eq. (1). A critical pressure or elevation exists each night. Stations above this elevation show an increase in temperature during the night, while those below it show a decrease. Cooling rates increase with decreasing elevation in the basin. A possible explanation of this behavior is that we are observing the combined effects of local radiative cooling and advective warming due to entrainment of external air. At sites above the critical elevation the advective effects are dominant and below it radiative effects begin to have the stronger influence. The lower a site is in the basin, the less influence advection has; consequently the observed cooling rates are greater.

5. ACKNOWLEDGMENTS

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