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OAK RIDGE NATIONAL LABORATORY

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TEMPERATURE INVERSIONS IN THE VICINITY OF OAK RIDGE, TENNESSEE, AS CHARACTERIZED BY TETHERSONDE DATA

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ACRONYMS AND ABBREVIATIONS

amsl	above mean sea level
ATDD	Atmospheric Turbulence and Diffusion Division
°C	degrees Celsius
ft	feet
hPa	hectopascal
K	Kelvin
LT	local time
m	meter
mph	miles per hour
s	second

1. BACKGROUND

Accidental releases of hazardous materials to the atmosphere may result from fires that create a buoyant plume which may rise several hundred meters above the ground. For such buoyant release cases, estimates of ground-level concentrations may be as much as a factor of 100 lower than similar, nonbuoyant releases. For the Oak Ridge Reservation, safety analyses often examine buoyant release accident scenarios and resulting downwind, ground-level consequence estimates. For these analyses, careful consideration of buoyant plume rise is important.

Plume rise can be limited by a stable vertical atmospheric temperature profile, commonly called an inversion, where the air temperature increases with height. There is a concern that inversions may interact with the complex terrain on the Oak Ridge Reservation, particularly at the Y-12 Plant, which is located in a relatively shallow [60–80 m (200–260 ft) deep] but narrow valley, to trap the plume and increase ground-level consequences. The purpose of this paper is to review the available meteorological data that provide information on inversions in the Oak Ridge area.

2. INTRODUCTION

At night, ground-based inversions commonly form as the surface cools by radiation. In dispersion modeling, these radiation (or surface) inversions are called a stable atmospheric condition, which can be categorized into three classes: E (slightly stable), F (moderately stable), and G (strongly stable) (Turner 1994). Stability class E does not always indicate a radiation inversion, but classes F and G always do.

During the morning, when the ground surface is heated by sunlight, there is usually a vertically well-mixed, convective (i.e., turbulence caused by large thermal eddies) layer that is capped at some altitude by an inversion. This convective layer is called the mixed layer and the top of the mixed layer, at the capping inversion, is called the mixing height. In dispersion modeling, the turbulent atmosphere below the mixing height is categorized into three classes: A (strongly unstable), B (moderately unstable), and C (slightly unstable). Two types of inversions can cap the mixed layer for extended periods of time: frontal and subsidence. A frontal inversion occurs when a warm air mass overruns a cold air mass. A subsidence inversion can occur when cool air in an anticyclone (high pressure system) slowly sinks (subsides) and warms adiabatically (i.e., no heat is transferred into or out of the sinking air). Subsidence inversions may persist for several days.

A neutral (i.e., not stable or turbulent) atmosphere occurs during cloudy and/or high wind conditions and is categorized as stability class D. Neutral conditions may occur during the day and night, and also may be capped by an upper-level inversion. Neutral atmospheric stability with moderate to high winds often results in the highest consequence estimates for buoyant release cases because the relatively strong winds limit the height of final plume rise. Maximum consequence estimates under these conditions generally occur at downwind distances that are relatively close to the release.

Measurements of the vertical profile of the atmosphere (soundings) are used to determine the presence of both surface and elevated (subsidence and frontal) inversions. Soundings are commonly obtained by instruments attached to free-floating balloons that relay data back to a ground-level station or earth-orbiting satellite via radio signals (radiosondes), or to balloons attached to a line for retrieval after data collection (tethersondes). The remainder of this report discusses (1) tethersonde data from balloons launched in Oak Ridge, (2) limitations of these tethersonde data in providing information about local inversions, (3) general information about inversions obtained from these data, (4) frequency of inversions as a function of altitude, (5) comparisons of the tethersonde data to Y-12 surface meteorological data, (6) a calculation of plume penetration into an inversion based on tethersonde data, and (7) conclusions about radiation inversions in the area.

3. TETHERSONDE DATA COLLECTED IN OAK RIDGE

From 1981 to 1983, tethersondes were launched in front of the buildings housing the Atmospheric Turbulence and Diffusion Division (ATDD) of the National Oceanic and Atmospheric Administration. These buildings are located in Gamble Valley, bordered on the northwest by East Fork Ridge and the southeast by Pine Ridge. The Y-12 Plant is located in Bear Creek Valley, southeast of the launch site, which is bordered on the northwest by Pine Ridge and southeast by Chestnut Ridge. The elevation of the ATDD site is about 270 m (886 ft) above mean sea level (amsl), with the top of Pine Ridge at an average elevation of about 350 m (1160 ft) amsl. The elevation of the Y-12 Plant varies from 270 to 300 m (886 to 985 ft) amsl.

Balloons were launched at approximately 1-hour intervals, mostly between about 0400 and 1000 local time (LT), on the first three or four days of each month, weather permitting. The balloons ascended to approximately 770 m (2350 ft) amsl [500 m (1640 ft) above the ground], and were brought back—a process typically taking more than one-half hour. Data were archived for specific elevations at 10 meter intervals. Ascent and descent data at each elevation were averaged to produce a composite vertical profile, a process that tends to temporally smooth the data closest to ground level while providing relatively instantaneous samples near the highest level of ascent.

Data were recorded for 300 balloon ascents over a period from October 1981 through September 1983. A summary of the number of launches by calendar months is given in Figure 1, and a more detailed summary by calendar month and time of day is given in Figure 2. Archived variables include local time, height (m, amsl), temperature (°C), potential temperature (converted to °C), mixing ratio of water vapor to "dry" air (g/kg), air pressure (hPa), wind speed (m/s), and wind direction (in degrees, and by u and v components). Due to the limited nature of the scope of this report, only temperature is discussed further.

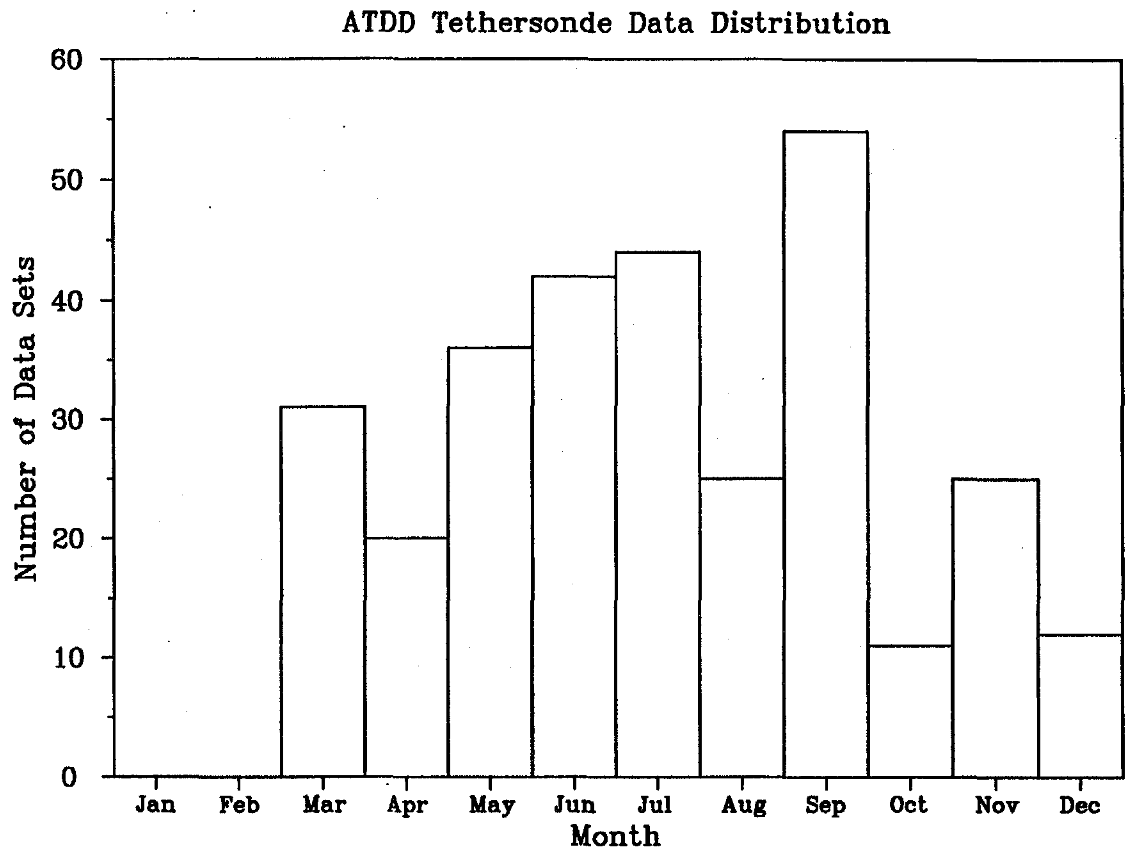

Figure 1. Number of soundings as a function of calendar month.

ATDD Tethersonde Data – Dates and Times of Collection

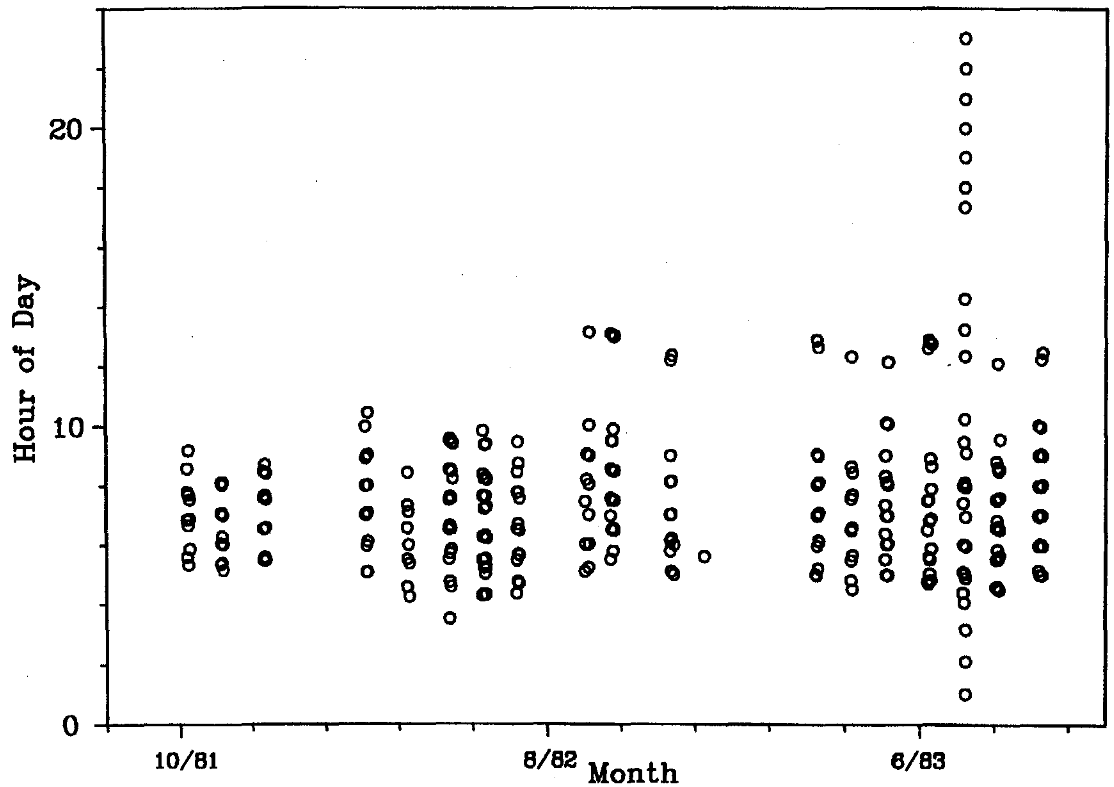

Figure 2. Dates and hours of day for which tethersondes were launched.

4. LIMITATIONS OF THE TETHERSONDE DATA

In terms of analyzing the tethersonde data for information regarding inversions, the following major limitations were found:

- About 75% of the data are from the warmer months (April through September), and no launches were made during January or February of 1982 or 1983 (see Figure 2).
- As shown in Figure 2, very few data were collected past 1000 LT. The data allow some reasonable generalizations for each hour from 0400 to 1000 LT for summer and 0500 to 0900 LT for winter. Reasonable generalizations are not possible past 1000 LT for these tethersonde data.
- Although inversions well above the ground (i.e., subsidence or frontal inversions) are identifiable in the data, they occur on less than 10% of the soundings, and would require more analysis of individual soundings to determine which of them are real (persisting from hour to hour during the same day) and which are likely to be data anomalies. These upper-level inversions occur above elevations of around 500 m (1650 ft) amsl, which are well above the top of Pine Ridge.

Because few afternoon data, or few data from more than an elevation of about 500 m (1650 ft) amsl, are available for identification of strong subsidence or frontal inversions, the usefulness of the tethersonde data to determine mixed layer heights (i.e., bottom of an upper-level inversion which would cap plume rise) is limited. The data show no evidence of subsidence and frontal inversions occurring below the top of Pine Ridge. (Such mixed layer height information is generally available from radiosonde data.) The data do provide some useful information on radiation inversions in the Oak Ridge area. The remainder of this paper discusses morning radiation inversions and their subsequent break up in the hours after sunrise.

5. RADIATION INVERSIONS IN THE OAK RIDGE AREA

Average temperature profiles for summer (defined as May through August for this paper) and winter (defined as November through February for this paper), on an hour-by-hour basis, are shown in Figure 3. These averages incorporate all conditions during these months, including unstable and neutral (i.e., non-inversion conditions where temperature decreases with height). Data from March, April, September, and October are not included in these average profiles because the time of sunrise changes appreciably on a daily basis during these months and information on the timing of radiation inversion breakup would not be clearly shown if these months were included.

On average, radiation inversions occur before sunrise. Radiation inversions are usually at least 150 m (490 ft) deep [i.e., they extend from 270 m to at least 420 m amsl (886–1380 ft amsl)]. The average depth of the inversion is consistent with general surface inversion depths, as discussed in Hanna, Briggs, and Hosker (1982). Although not revealed in the tethersonde data,

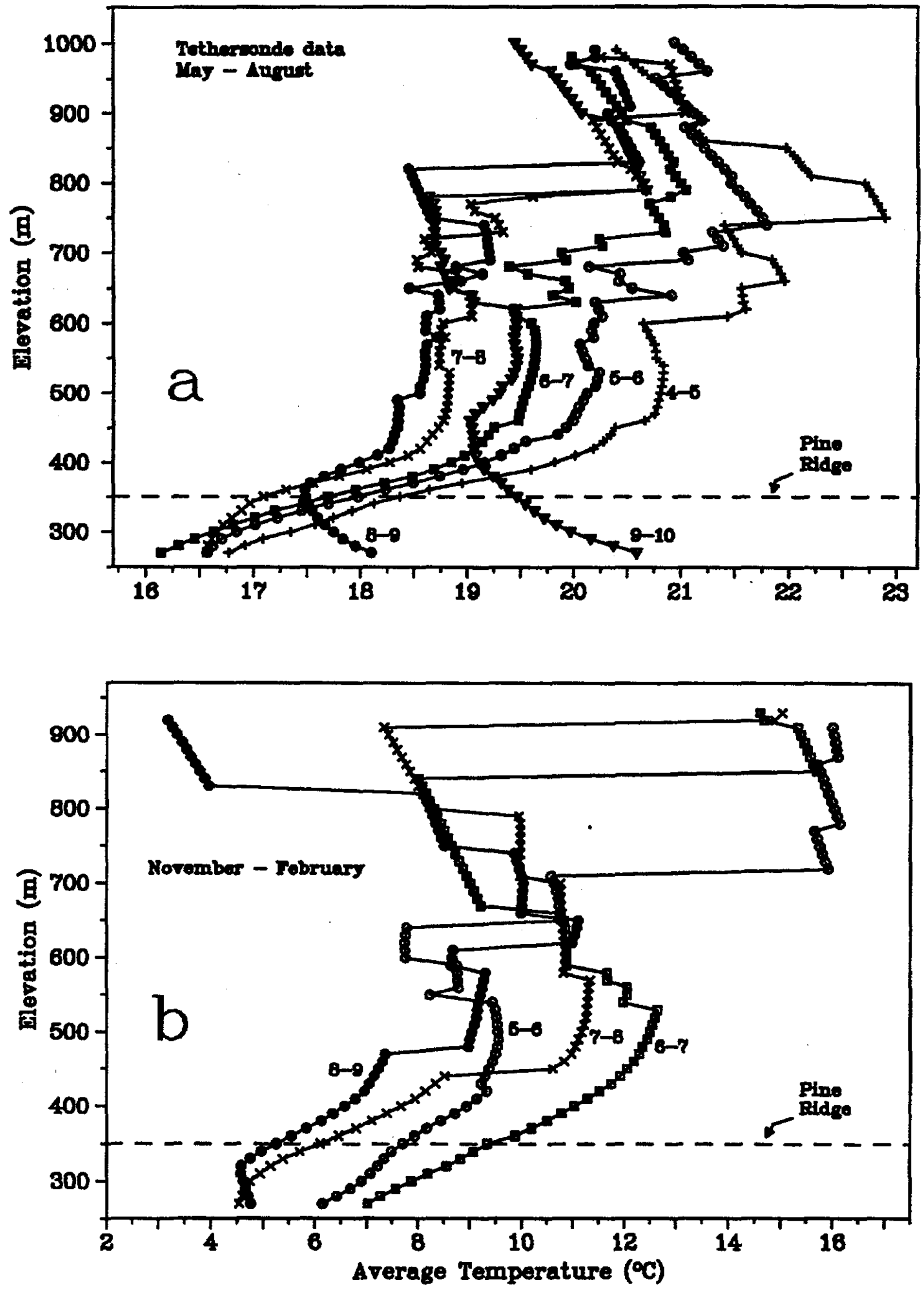

Figure 3. Mean temperature profiles for morning hours during (*a*) summer and (*b*) winter. The dashed lines indicates the elevation of the top of Pine Ridge.

radiation inversions generally form shortly after sunset, with depth above the surface increasing during the night. The rate of increase is probably greatest after sunset and slows just before sunrise. A study of inversions in the Oak Ridge Area by Culkowski (ca. 1960) shows that radiation inversions occur, on average, about 10 hours per night.

As shown in Figure 3a, the summer radiation inversion begins to weaken between 0700 and 0800 LT (hour 7–8 in Figure 3a). Between 0800 and 0900 LT (hour 8–9 in Figure 3a), the radiation inversion is no longer identifiable at ground level because the ground has warmed up and heated the air near the surface. Lapse (temperatures decreasing with height) conditions are evident up to about 100 m (330 ft) above the surface (i.e., the height of the mixed layer is 100 m) between 0800 and 0900 LT, and in the following hour (9–10 in Figure 3a), lapse conditions extend up to about 200 m (660 ft) above the surface. Again, only a few data were recorded past 1000 LT; therefore, generalizations past this time are not possible. The breakup of the radiation inversion occurs quickly in the summer, with the height of the mixed layer rising above the ridge tops [i.e., 60–80 m (200–260 ft) above the valley floor] within 2 hours after sunrise.

The winter inversion seems to break up between 0800 and 0900 LT (shown as hour 8–9 in Figure 3b), where the mixed layer height is about 50 m (165 m). Although sufficient data are not available past 0900 LT, the average winter mixing height probably rises above the ridge tops between 0900 and 1000 LT.

6. FREQUENCY OF INVERSIONS AT DIFFERENT ELEVATIONS

Figures 4 (summer) and 5 (winter) show the frequency of temperature increases (inversions, indicated by solid dots and dashed lines), or decreases (lapse conditions, indicated by X's and solid lines) in each 10-m (33-ft) elevation increment, for each morning hour for which sufficient data are available (0400 to 1000 LT during summer and 0500 to 0900 LT during winter). Unlike the average temperature profiles shown in Figure 3, these figures separate instances of lapse and inversion conditions. Only frequencies of each condition are represented; the magnitude of temperature change with height is not shown in these figures.

The horizontal axes in Figures 4 and 5 represent the frequency of temperature increases, or decreases, for the corresponding 10-m elevation ranges. The total percentage (inversion plus lapse conditions) is scaled to the amount of data retrieval per launch—i.e., it drops off from 100% near the surface to lower values aloft, to indicate the lower percentage of data recovery per launch at higher elevations. For example, the decrease in frequency of lapse conditions (X's) just above 630 m (2070 ft) in Figure 4a is not accompanied by an increase in the frequency of inversions, indicating a loss of about 20% of the temperature data above that level. Virtually no data were collected above about 800 m (2625 ft) amsl.

Results for the 0400 to 0500 LT during summer are given in Figure 4a. The frequency of temperature inversions (indicated by solid dots) in the first 20 m (66 ft) above the ground is about 65%; conversely, the frequency of lapse conditions (indicated by X's) at the same elevations is about 35%. The frequency of temperature inversions increases to about 95% in the next 20 m, and continues at that frequency for about 50 m before declining again.

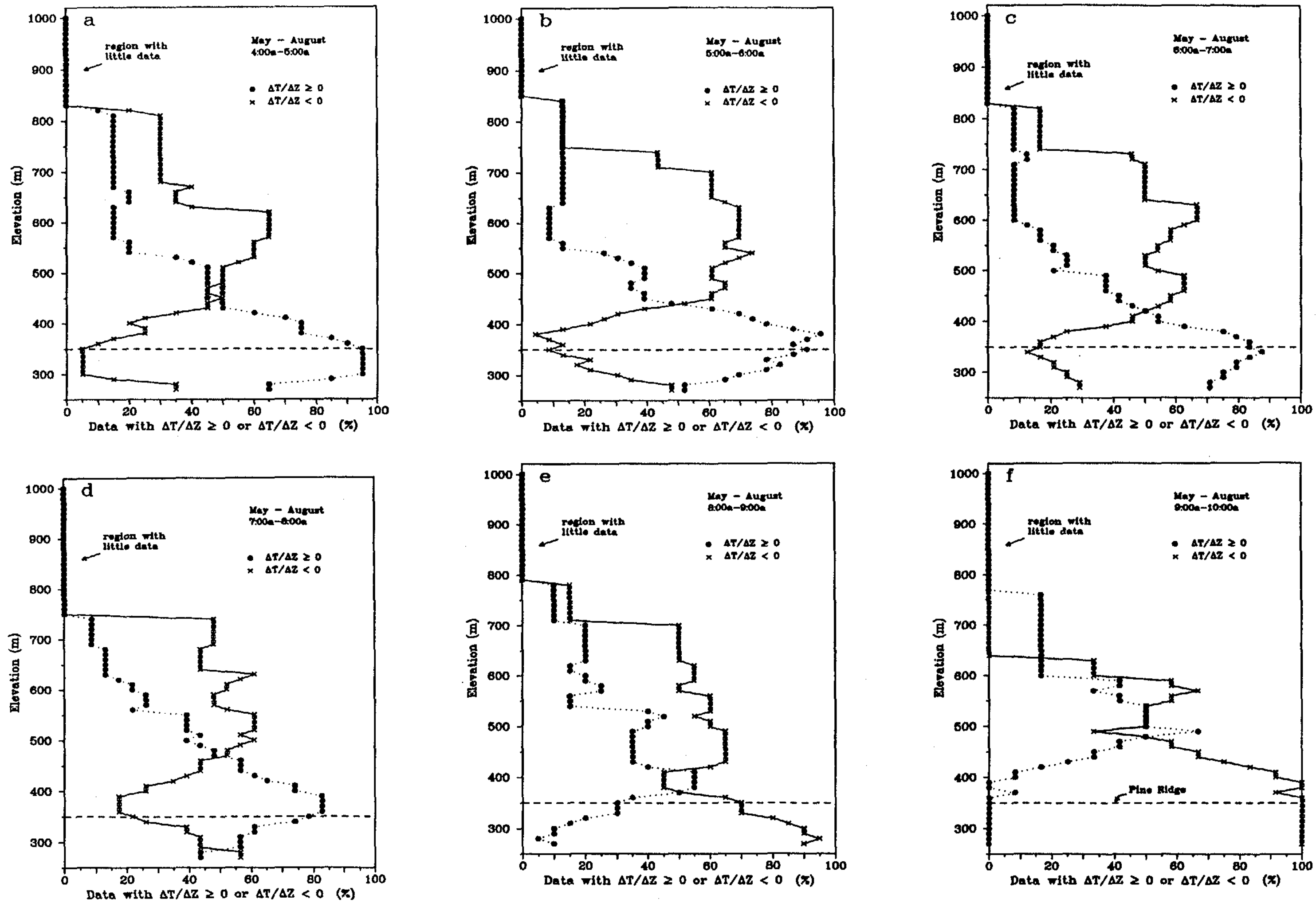

Figure 4. Frequency of inversion conditions (solid dots) and lapse conditions (X's) for each of 10 m (33 ft) of elevation increase, for summer hours. The total percentage (solid dots plus X's) decreases in proportion to the data retrieval rate. The dashed lines indicate the elevation of the top of Pine Ridge.

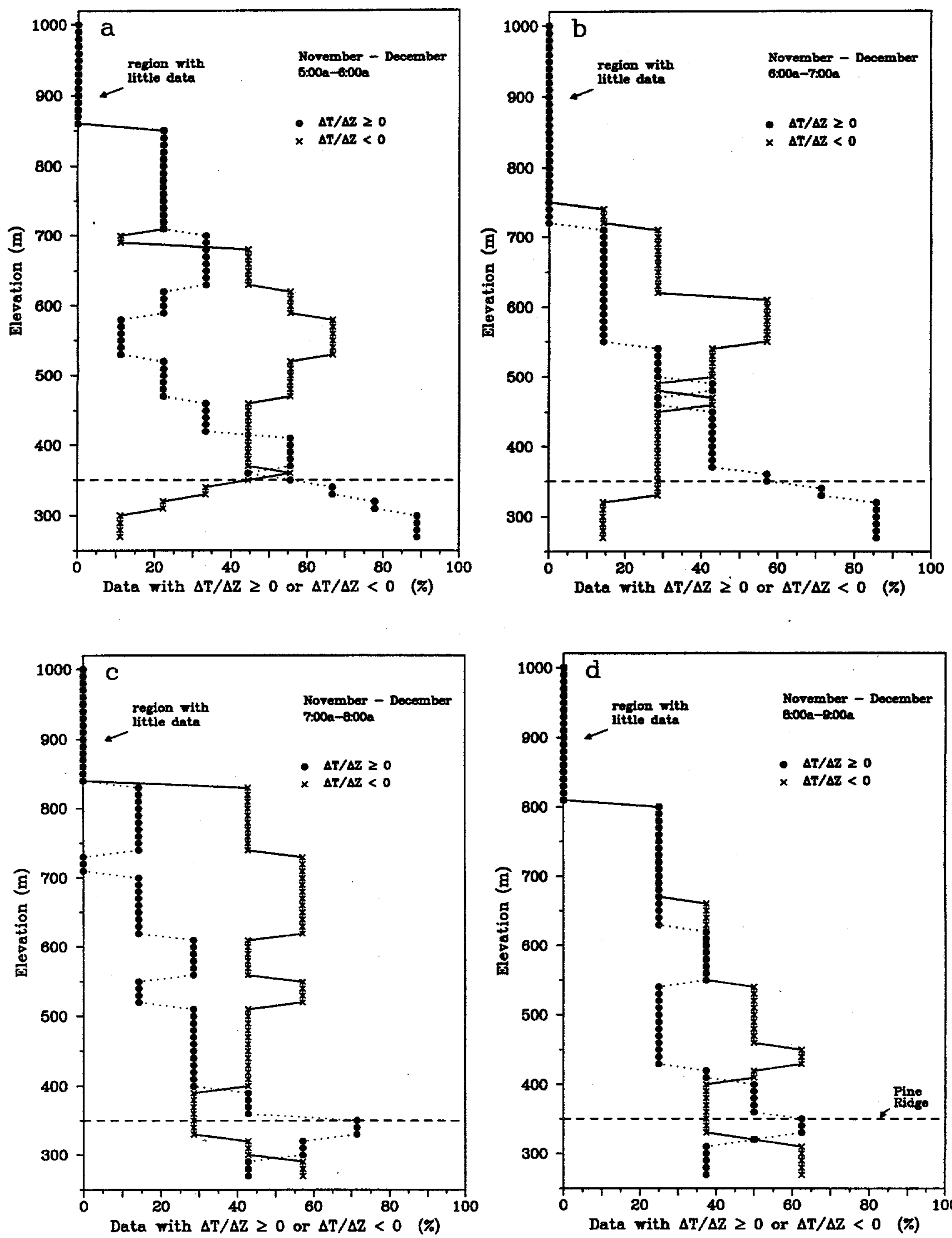

Figure 5. Frequency of inversion conditions (solid dots) and lapse conditions (X's) for each of 10 m (33 ft) of elevation increase, for winter hours. The total percentage (solid dots plus X's) decreases in proportion to the data retrieval rate. The dashed lines indicate the elevation of the top of Pine Ridge.

In Figure 4b, the frequency of inversion conditions between 0500 and 0600 LT gradually increases from only about 50% in the first 20 m above the surface to about 90% at elevations of about 360 m (1180 ft) amsl [90 m (295 ft) above the surface]. Frequency remains relatively constant to an elevation of about 420 m (1380 ft) amsl before a gradual decline in frequency begins. The gradual increase in inversion frequencies from the surface to an elevation of 360 m amsl is also evident in the data for the next hour (0600 to 0700 LT), shown as Figure 4c; the frequencies at the lowest levels are about 20% greater, however, and they increase with height at a lower rate than for hour 0500 to 0600 LT. The frequencies in Figure 4c then continue a general decline at higher elevations, as in the previous hour. Between 0700 and 0800 LT (Figure 4d), the frequency of inversions is about 50% up to an elevation of 320 m (1050 ft) amsl (i.e., the first 50 m above the surface), and increases to an 80% frequency at elevations from about 370 m (1210 ft) to 410 m (1350 ft) amsl [100 m (330 ft) to 140 m (460 ft) above the surface] before beginning a general decrease with elevation at about the same height as it did in the earlier hours.

As shown in Figure 4d, between 0700 and 0800 LT, the inversion frequencies drop to below 50% in the first 20 m (66 ft) above the surface, and below 65% for elevations between 290 m (950 ft) to 320 m (1050 ft) amsl [20 m to 50 m (164 ft) above the surface]. This is the first full hour of daylight when surface warming occurs and the radiation inversion begins to break up. Between 0800 and 0900 LT, inversions are relatively infrequent between the surface and 370 m (1210 ft) amsl [i.e., in the first 100 m (330 ft) above the surface] (Figure 4e). Near-surface inversions in summer were virtually never observed to an elevation of about 420 m (1380 ft) amsl [i.e., within about 150 m (492 ft) of the surface] between 0900 and 1000 LT (Figure 4f). The frequency of lapse conditions is always about 60% in the 500 m (1640 ft) to 600 m (1970 ft) amsl elevation range. This suggests that the mixed layer penetrates this far upward (230–330 m above the surface) by late morning on about 60% of the summer days. During summer, inversion conditions below the ridge top [i.e., below elevations of about 350 m (1160 ft)] have a frequency of less than 5% by about 1000 LT.

The greatest inversion frequencies do not occur within about 30 m of the surface during the very early morning hours of summer (Figures 4a and b). The cause of this is uncertain. A study by Hosler (1961) examining surface inversions in eastern Tennessee suggests an 80% frequency of surface inversions in summer, but does not always indicate the height interval of the measurements on which the temperature difference is based. If measurements were summarized over a larger elevation interval near the surface, results would likely have been closer to the 80%value cited by Hosler (1961) and indicated by the temperature differences between elevations of 280 m (919 ft) and 370 m (1210 ft) amsl [10 m (33 ft) and 100 m (330 ft) above the ground], as discussed in the following section.

Because of the relatively small data sample for the winter months, inversion-frequency summaries by elevation in Figures 5a–d are not as smooth as those for the summer months. Also, the hours for which results are presented are limited to 0500 through 0900 LT.

As shown in Figures 5a (0500 to 0600 LT) and 5b (0600 to 0700 LT), inversions are present about 90% of the time at elevations up to 320 m (1050 ft) amsl and the frequency generally declines over the next 300 m (985 ft) to an elevation of 620 m (2030 ft) amsl.

Between 0700 and 0800 LT, the frequency of surface inversions (Figure 5c) has decreased dramatically from that of the previous hour. This is not clearly reflected in the average vertical temperature profiles for winter hours (Figure 3b), which include instances of lapse conditions as well as inversions. During winter, the radiation inversion may begin to break up at the surface as early as 0800 LT. By 0900 LT, the inversion break up is well established and agrees with the average vertical temperature profile (Figure 3b) with an average mixing height of about 320 m (1050 ft) amsl [50 m (165 ft) above the surface].

7. COMPARISON OF TETHERSONDE DATA WITH Y-12 SURFACE METEOROLOGICAL DATA

Conditions represented in the data from a tethersonde launched at the ATDD site agree with surface meteorological data measured at the Y-12 Plant. Hourly average temperature data are available at levels of 286, 306, and 376 m (938, 1004, and 1234 ft) amsl [10, 30, and 100 m (33, 98, and 330 ft) above the ground] at a meteorological tower located at the Y-12 Plant about 1500 m (0.9 mile) to the southeast of the ATDD site. [The instruments at 100 m are about 26 m (85 ft) above the top of Pine Ridge.] Figures 6a and 7a show temperature differences between the 100 m and 10 m levels calculated for each hour of the day during the summer (May through August) and winter (November through February) of 1996. Figures 6b and 7b show the corresponding temperature differences in the tethersonde soundings between the first 10 m and 100 m of ascent. Data were for the tower and tethersonde were measured over different years.

During summer, the tethersonde and tower data agree well, as shown in Figure 6. About 80–90% of the summer days have temperature inversions in the first 100 m above the ground during the earliest morning hours. This is in general agreement with the 80% value given by Hosler (1961). Between 0900 and 1000 LT (hour 9–10 in Figure 6) surface inversions occur less than 5% of the time in the summer.

Tower data indicate that inversions occur on 50–55% of the winter days (Figure 7b), which is slightly lower than the 60% value given by Hosler (1961). Tethersonde data indicate lapse conditions are present in the early morning hours, but do not occur more than 20% of the time until between 0800 and 0900 LT (hour 8–9 on Figure 7a). Early morning data from the tethersondes suggest that inversions occur on at least 85% of the winter days (Figure 7a), which is about the same as for summer, and about 25% higher than the percentage for winter indicated by Hosler (1961). Unlike the situation for summer, the tethersonde data appear to be quite different from the tower data. The small sample size for the winter tethersonde data is a likely contributor to this large discrepancy.

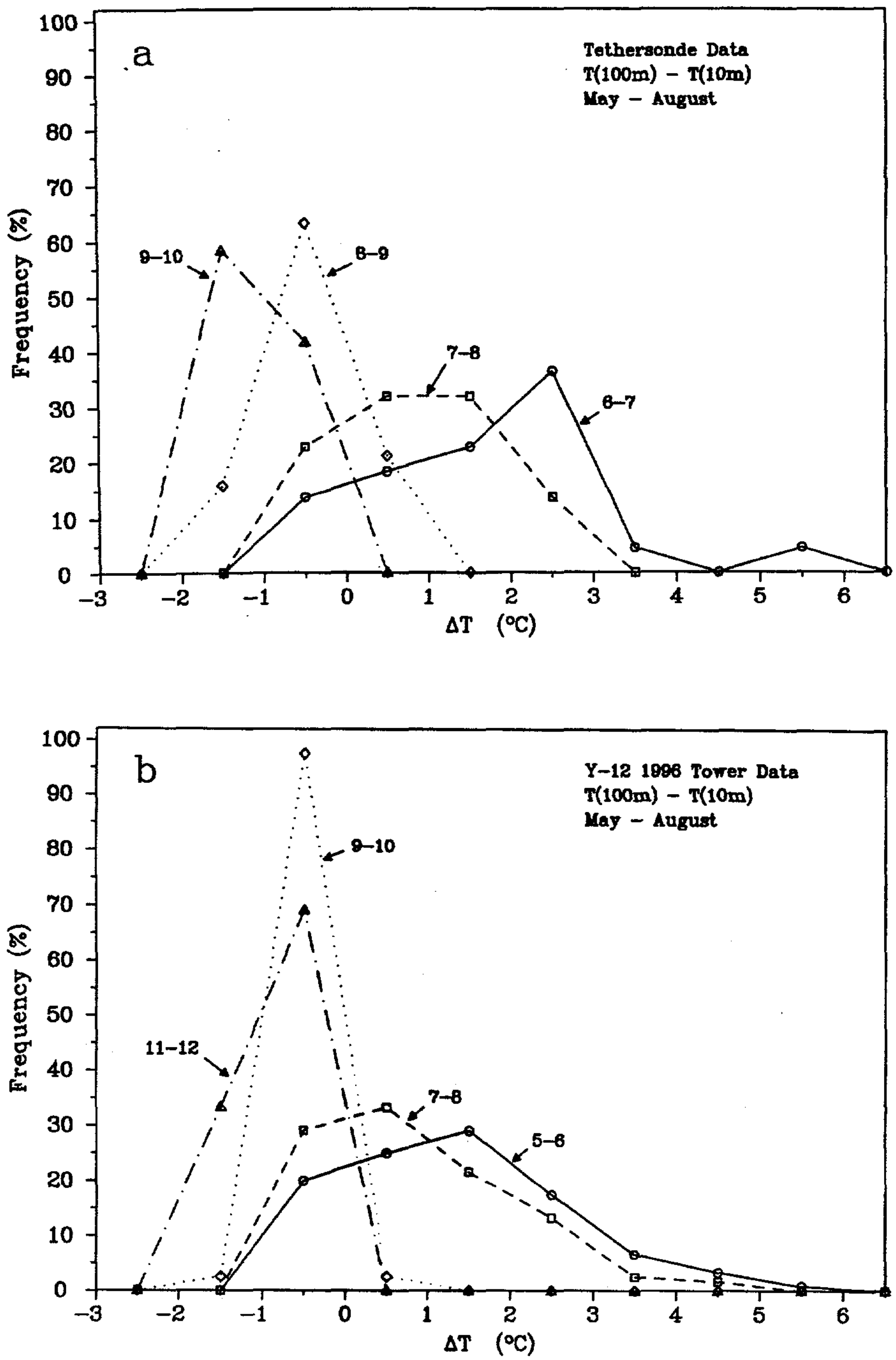

Figure 6. Temperature at 100 m (330 ft) minus temperature at 10 m (33 ft) for summer morning hours, taken from (a) tethersonde data and from (b) the meteorological tower in Bear Creek Valley.

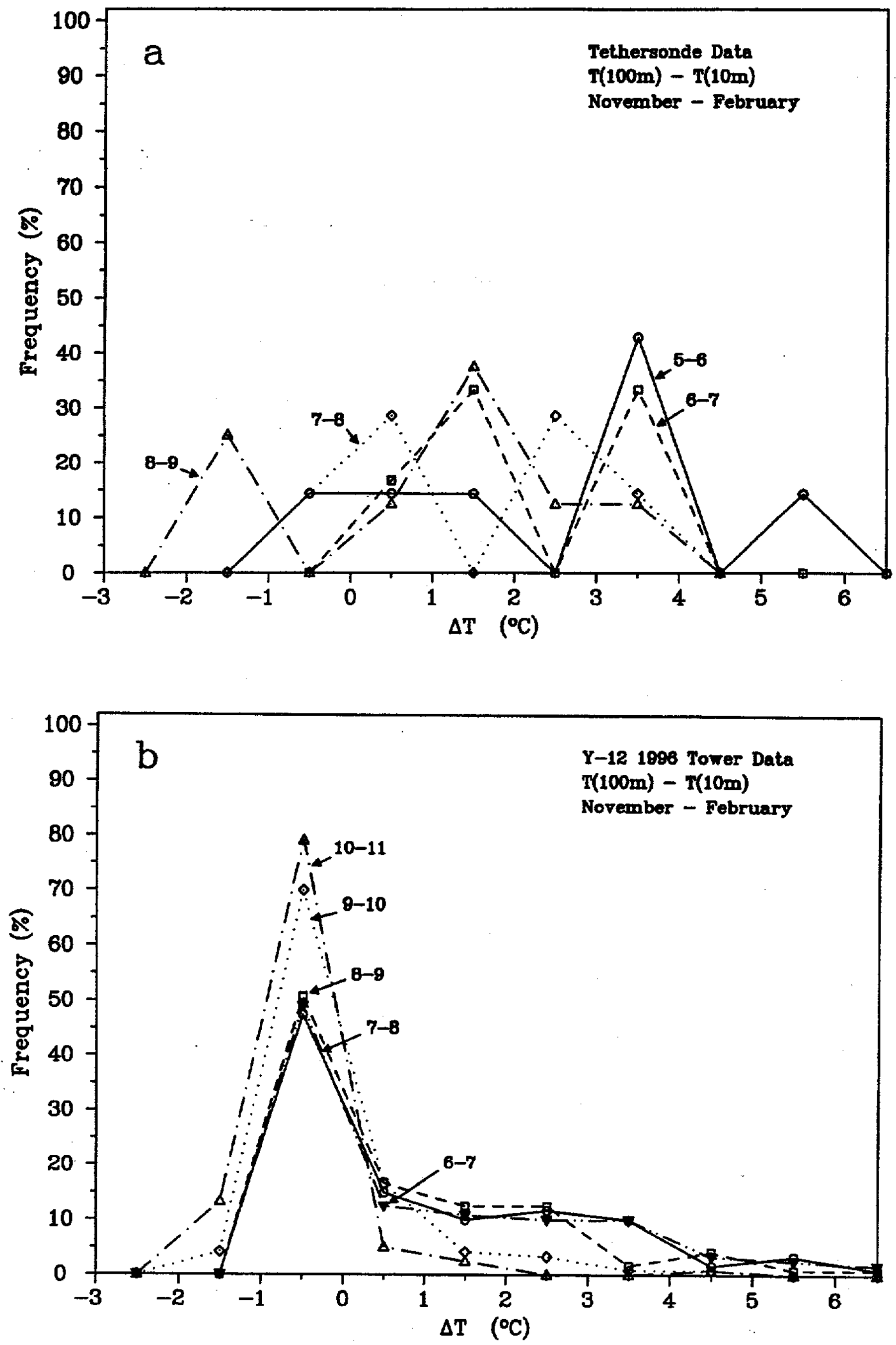

Figure 7. Temperature at 100 m (330 ft) minus temperature at 10 m (33 ft) for winter morning hours, taken from (a) tethersonde data and from (b) the meteorological tower in Bear Creek Valley.

8. CALCULATION OF PLUME PENETRATION BASED ON TETHERSONDE DATA

Briggs (1984), has investigated the behavior of buoyant plumes in terms of their buoyancy flux, F_0 (m^4/s^3), defined as:

$$F_0 = \left(\frac{g}{T_p}\right)(T_p - T_a)\, r^2 w \qquad \textbf{(1)}$$

where:

T_p is the plume temperature at the release point (K),
T_a is the ambient air temperature at the release point (K),
r is the radius (m) of the plume at the release point, and
w is the exit velocity (m/s) (upward) of the plume at the release point.

The resistance of an inversion to penetration by a buoyant plume is described in terms of potential temperature θ (K), defined as:

$$\theta = T\left(\frac{1000}{p}\right)^{0.286} \qquad \textbf{(2)}$$

where:

T is an ambient air temperature (K), and
p is the corresponding air pressure (kPa) (also recorded in the tethersonde data).

According to Briggs (1984) a buoyant plume will penetrate into an elevated inversion if:

$$F_0 > g^{1.5}\left(\frac{z_{el}}{6.9}\right)^{2.5}\left(\frac{\Delta\theta_i}{\theta_a}\right)^{1.5}$$

(3) for a *vertical* plume

$$F_0 > g\left(\frac{z_{el}}{2.5}\right)^{2}\left(\frac{\Delta\theta_i}{\theta_a}\right) U$$

(4) for a *bent-over* plume

where:

g is the acceleration due to gravity at the surface (9.81 m/s^2),

z_{el} is the height of the bottom of the inversion layer above the ground surface (m),
$\Delta\theta_i$ is the potential temperature difference from the top to the bottom of the inversion layer (K),
θ_a is the potential temperature at the bottom of the elevated inversion layer (K),
U is the wind speed (m/s) at the height of the inversion layer defined as:

$$U = u_{10}\left(\frac{z_{el}}{10\ \mathrm{m}}\right)^{p} \quad \textbf{(5)}$$

where:

u_{10} is the wind speed (m/s) at 10 m, and
p is the wind profile exponent for neutral stability equal to 0.15.

Note that Equations 3 and 4 are intended to calculate the threshold at which a plume would penetrate an elevated inversion; they are not intended to provide information on the behavior of the plume once it penetrates the inversion.

Table 1 shows calculated values of buoyancy flux for seven different release scenarios (intervals) in which the initial plume radius, r, varies from 2.75 m (9 ft) to 36.97 m (121.3 ft), and values for other input variables are T_p = 866.3 K, T_a = 255.2 K, w = 9.0 m/s [20.1 miles per hour (mph)], and u_{10} = 3 m/s (6.7 mph). The resulting calculated values of F_0 range from about 470 m^4/s^3 (54,466 ft^4/s^3) to 85,000 m^4/s^3 (9,859,173 ft^4/s^3).

Table 2 shows values for the right-hand side of the equation (the inversion resistance) over various inversion heights and elevated inversion conditions given by the tethersonde data. For vertical plumes, the values of the inversion resistance range from about 12 m^4/s^3 (1,391 ft^4/s^3) to 340 m^4/s^3 (39,400 ft^4/s^3). For bent-over plumes, the values of inversion resistance range from about 380 m^4/s^3 (44,036 ft^4/s^3) to 5400 m^4/s^3 (625,776 ft^4/s^3). Comparing the values in Tables 1 and 2, the calculated buoyancy fluxes always exceed the maximum inversion resistance for vertical plumes. For bent-over plumes, the first release case (interval 1) can penetrate only one of the specified inversion conditions, and plume rise may be capped for the others. Also, in the second interval case, a bent-over plume may not penetrate inversions with a base elevation greater than about 100 m. However, all of the other release cases appear to have sufficient buoyancy to penetrate into elevated inversions, even for bent-over plumes.

Table 1. Plume buoyancy fluxes calculated for various release conditions

Interval	Plume radius, r (m)	Buoyancy flux, F_0 (m^4/s^3)
1	2.75	471.0
2	4.64	1,340.9
3	10.39	6,723.4
4	14.69	13,440.0
5	36.97	85,124.5
6	36.67	83,748.6
7	35.48	78,401.2
8	33.92	71,658.4

Table 2. Elevated inversion resistances calculated from the ATDD tethersonde data

Inversion height, z_{el} (m)	Inversion resistance (m^4/s^3)		
	Summer 8-9	Summer 9-10	Winter 8-9
	Vertical Plumes		
80	25.2	12.4	34.9
100	44.1	21.7	61
150	122	59.7	168
200	249	123	345
	Bent-over Plumes		
80	608	379	755
100	982	612	1220
150	2350	1460	2920
200	4360	2720	5410

9. CONCLUSIONS

The Oak Ridge tethersonde data provide useful information about early morning radiation inversions and their break up. However, only limited data are available for November through February, and those data are only for days prior to the winter solstice, which is not the coldest part of the year. The available data indicate that inversion depths are typically between about 150 m (490 ft) and 300 m (984 ft), and breakup begins between 0800 and 0900 LT, with the associated height of the mixed layer equal to about 50 m (164 ft) (i.e., just below the ridge tops). The height of the mixed layer is likely to rise above the ridge tops after 0900 LT, as indicated by data from the 100-m (330-ft) instrument tower in Bear Creek Valley. For summer, the inversion depth appears to be between 150 m (490 ft) to 250 m (820 ft), and when break up occurs, the mixing height extends to an elevation of 370 m (1210 ft) (i.e., well above the ridge tops) before 0900 LT.

The tethersonde data suggest that if an accidental buoyant release were to occur during the early morning hours (before daylight has warmed the ground surface), plume rise would be limited by stable atmospheric conditions from the surface to the top of the inversion. Under this situation, the use of plume rise equations valid for a stable atmosphere would be appropriate. If the plume was very buoyant, as would be the case for a release resulting from a major fire, it would probably penetrate the top of the surface inversion layer into neutral or unstable atmospheric conditions above the inversion layer. In this case, horizontal and upward dispersion would be enhanced and subsequent return of released material to the surface would be strongly limited by the underlying inversion. Therefore, ground-level concentrations would be greatly reduced. Shortly after sunrise, the surface radiation inversion would break up and the plume could be brought to the ground by the thermal turbulence (i.e., unstable atmospheric conditions).

During inversion breakup, plume rise may be capped at a mixing height (i.e., bottom of the radiation inversion) below the ridge top [i.e., below an elevation of about 320 m (1050 ft) above sea level]. This capping would occur over a very short time period (typically a fraction of an hour) during the summer and for no more than one and one half hour during winter under worst-case conditions. Under this capping scenario, the use of plume rise equations for neutral or unstable atmospheric conditions would be appropriate until the rising plume centerline reaches the mixed layer height. At this point, upward vertical dispersion would be strongly limited if the plume was not sufficiently buoyant to penetrate the inversion. This condition, called inversion break up fumigation, allows vertical dispersion in the downward direction only. Inversion break up fumigation would be a temporary event and would occur less than or equal to about 4% of the time on an annual basis [calculated as a one and a half hour event maximum duration that would occur during radiation inversion conditions—about 70% the year Hosler (1961)]. However, as shown earlier, any plume from a large fire [diameter > 20 m (65 ft)], and vertical plumes from smaller fires [diameter > 5.5 m (18 ft)] appear to have sufficient energy to penetrate into an inversion as the inversion continues to break up. In these cases, ground-level concentrations would be greatly reduced.

As stated earlier, the tethersonde data do not show persistent elevated inversions with bases occurring below the ridge tops in the Oak Ridge area. Some evidence of subsidence and frontal inversions are seen in the data, but the heights of these inversions are well above the top of Pine Ridge.

10. REFERENCES

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