Marked Surface Inversions and Wind Shear- A Safety Risk for Departing Aircraft

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Marked surface inversions occur most frequently in dry continental climates, where low atmospheric humidity allows heat transfer by long wave thermal radiation. In the northern latitudes, surface inversions reach their maximum intensity during the winter, when the incoming sun's radiation is negligible and radiative cooling is dominant during the long nights. Also, during winter, air mass boundaries are sharp, which also favors formation of marked surface inversions. The existence of these inversions and sharp boundaries increase the risk of wind shear. According to ICAO, there is an operational requirement that pilots be informed, prior to departure, of any marked inversion in the lower levels of the atmosphere up to 1000 feet above ground level. The information should refer to marked inversions exeeding a temperature difference of 10° C up to 1000 feet. According to ICAO, there also exists a need to determine the temperature range over which the information is operationally needed and the magnitude of the inversion required before a notification to pilots prior to departure is warranted.

Near Helsinki airport, measurements are made with a 1000-foot high weathertower used in routine aviation service and for research purposes. Wind measurements are made at four (4) heights by anemometers equipped with IR-radiators to prevent icing. Temperature is measured at eight (8) heights with platinum-100 termoelements. The statistics and cases presented in this paper were based on one-half hourly measurements made during the past four (4) years (1245 days).

Marked inversions occur mainly during winter months in Helsinki, see Figure 1. For example, during the observation period illustrated, 12 marked inversions occurred during December, which altogether lasted 74 hours. This is a three (3%) percent probability of the occurrence of such inversions. During January, the probability is nearly as high but decreases as spring advances. The absence of marked inversion during April may be explained by the humid conditions which exist due to melting snow. During this month, cyclone activity is also high, which means there is an advection of humid airmass from the Atlantic. During midsummer and autumn, no marked inversions occurred. This is because of the relatively warm sea in the summer, which normally freezes in winter.

The most probable time for an occurrence of a marked inversion is in winter (December - March). During the observation period, a marked inversion occurred on 23 days. This represents a six (6%) percent probability of occurrence of marked inversions, see Figure 2.

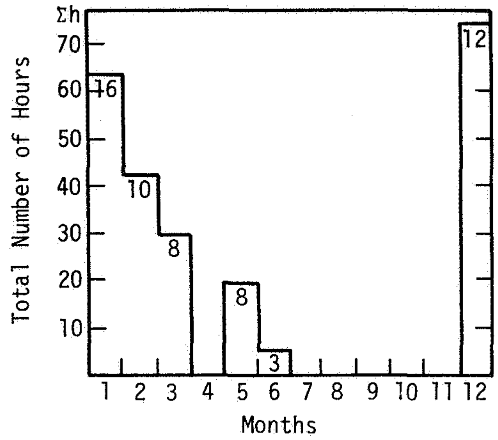

Figure 1. Monthly occurrence of marked inversions at Helsinki.

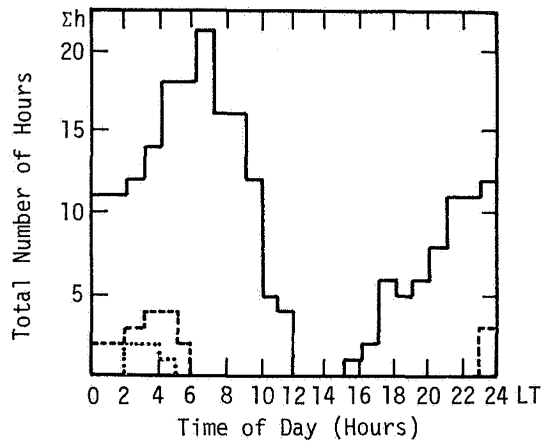

Figure 2. Hourly occurrence of marked inversions:
winter———;
spring------;
summer······

During the spring (April - May) marked inversions occurred only at midnight and early morning; and during the summer (June - September) inversions occurred only in the early morning. (Note that nights are extremely short during the summer.)

The strongest inversion detected during the total observational period, was ΔT = 15° C below 1000 feet (300 m), see Figure 3, profile 3. This inversion occurred in December. Profile 1 presents an extreme case of an inversion, in which the temperature rise occurs only above 100 m. This inversion took place in January during a warm advection. Profile 2 presents an extreme case, where the total temperature rise occurred in the lowest 20 m. This inversion was a radiation case in June.

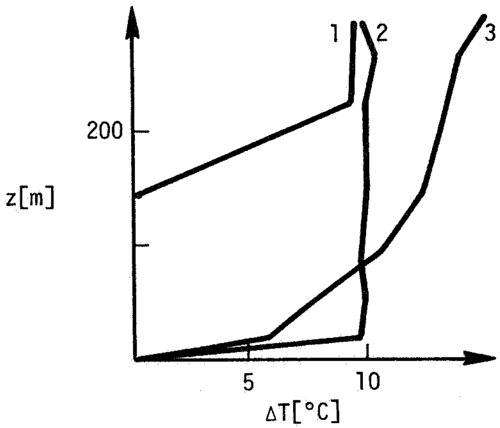

Figure 3. Examples of extreme cases, see text.

Table 1. Summary of marked inversion at Helsinki airport during the four-years observation period.

	winter	spring	summer	autumn
Surface temperature °C	-31 - -3	+1 - +9	+9 - +11	-
max. inversion °C/1000ft.	15	13	12	-
max. duration h	18	6	2	-
probability %	2.3	0.6	0.7×10^{-3}	-
average height m	230	200	160	-

It is well known that air stability increases the risk of wind shear. It may not, however, be as widely known that wind shear also occurs during extremely stable conditions. Profile (a) in Figure 4 shows an increase in wind speed from 6 kt at 20 m to 24 kt at 90 m and a simultaneous wind direction change ($\Delta\alpha$) of 50°. These conditions produce a wind shear magnitude of 9 kt/100 feet for the vector wind difference. For the case considered, the wind speed reaches a value of 34 kt at 300 m. In the second case indicated by (b), wind speed increases from 3 kt at 20 m to 24 kt at 220 m and the simultaneous wind direction change is 100°.

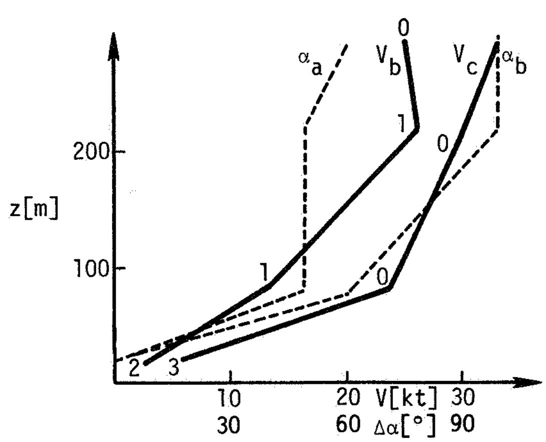

Figure 4. Examples of severe wind shears during periods of marked inversions.

Figure 4 is a plot of recorded wind speed variation with height. These wind profiles are based on two-minute mean values. The numbers on the curve at each measuring station indicate the maximum difference between wind speeds during the two-minute averaging period. It can be seen that the airstream is nearly "laminar", a maximum variation of only 3 kt or less occurs at any given measuring station.

Case (b) illustrates what may happen if the air traffic controller is unaware of the upper wind. He views the existing surface wind conditions as calm. Such a case is illustrated in Figure 5. Figure 5 presents a routine sounding made at Jyväskylä airport in Finland on November 1980. A DC-9-50 departed 0800 local time from runway 12. When turning on to course, a 180° turn at 1500 feet, the aircraft suddenly lost 500 feet in altitude and the pilot had to fight to maintain control of the aircraft. The apparent reason for this incident was departing into a strong tailwind created by a marked inversion.

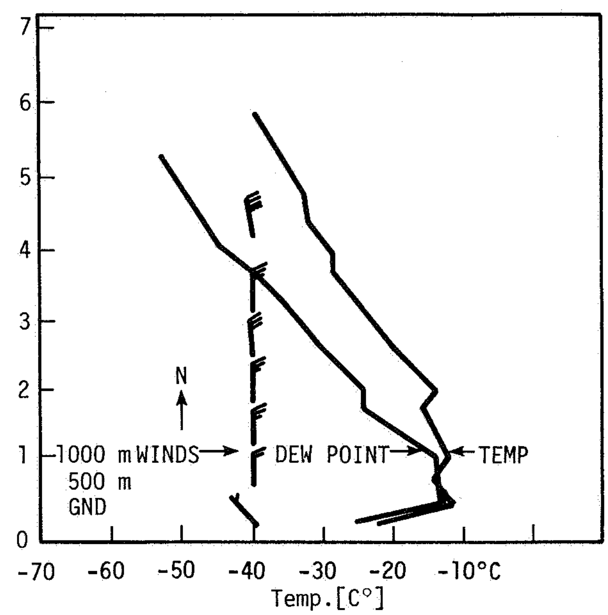

Figure 5. Prevailing weather conditions at Jyväskylä on November 11, 1980, when a DC-9-50 incident occurred.