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CLIMATOLOGY OF THE WINTER SURFACE TEMPERATURE INVERSION IN FAIRBANKS, ALASKA

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Abstract

The surface temperature inversion in the subarctic setting of Fairbanks, Alaska has been investigated. In winter the inversion is strong and semi-permanent; it separates the boundary layer from the air aloft and has great importance for pollution levels in town. We analyzed the changes that have occurred since radiosonde measurements began in 1957. For the time period from 1957 to 2004 a strong warming trend was observed in Fairbanks; the winter mean surface temperatures have increased by 3.3°C, more than for any other season.

The climatology of the surface-based temperature inversion is examined by analyzing the twice-daily radiosondes for December, January and February. While there has been no significant change in the frequency of occurrence of surface-based inversions, the depth as well as the intensity of the inversion has decreased.

The change in characteristics of the inversions is discussed and the role of cloudiness and winds is demonstrated. Increasing cloud amount weakens the surface inversion due to increased back radiation from the atmosphere, while strong winds aloft can erode the surface inversion due to forced mixing.

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1. Introduction

The role of the surface-based temperature inversion in the winter climate of the sub-arctic setting of Fairbanks, Alaska is well established in terms of the temperature regime (Wendler and Jayaweera 1972, Wendler and Nicpon 1975) as well as the role that it plays in the air quality in the city itself (Wendler 1975, Bowling 1986). Here we analyze a larger and more recent database to obtain changes in the frequency and intensity of the surface inversion in winter for the subarctic setting of Fairbanks.

2. Data and Methodology

The National Climatic Data Center Radiosonde Database has twice-daily radiosonde data from Fairbanks starting in 1957. December, January and February soundings from Dec 1957 to February 2004 were analyzed and classed into ‘surface inversion’ cases and ‘no surface inversion’ cases. Surface inversions might be lifted by solar radiation for the early afternoon sounding, and an elevated inversion is still being observed. Such cases are counted as ‘no surface inversion’. The conditions at the surface, as well as the mandatory reporting levels (850, 700, and 500 hPa) are compared.

If a sounding was determined to have a surface-based inversion, the sounding was examined individually to find the top of the inversion and then several values were calculated. The difference in temperature (ΔT) from the bottom to the top of the inversion and likewise, the depth of the inversion (Δz) from the surface in meters and the change in pressure (ΔP) from the surface to the top of the inversion in hPa were calculated. Additionally, the mean temperature gradient of each inversion was calculated and is denoted by the term ΔT/Δz and is measured in degrees C per 100m.

All trends discussed are based upon a linear least-squares regression model and tests for statistical significance were conducted.

3. Results

3.1 Frequency of occurrence and climatology of surface inversion and no surface inversion cases

Throughout the winter season (Dec-Feb), surface-based temperature inversions are very common, occurring 77% of the time. The remaining 23% frequently display elevated inversions. On a monthly basis, the highest frequency of surface-based inversions is found in January, on average the coldest month in Fairbanks, followed by December and February. It can be clearly seen in Table 1, that somewhat lifted inversions are common as the temperature at the surface is also colder than the temperature at the 850 hPa level in the ‘no surface inversion’ cases.

From winter 1957-58 to winter 2003-04, no appreciable trend can be found in the frequency of occurrence over the winter season as a whole, but when broken down into monthly data, both December and January showed decreases in the frequency of occurrence and February has seen a slight increase.

Table I. Climatology of ‘surface inversion’ and ‘no surface inversion’ winter soundings

	Inversion	Non-Inversion	Difference
Surface Temp. (°C)	-21.8	-16.8	+5.0
850 hPa Temp. (°C)	-11.1	-15.3	-4.2
700 hPa Temp. (°C)	-17.4	-19.0	-1.6
500 hPa Temp. (°C)	-32.9	-34.5	-1.6
Surface Pressure (hPa)	995.0	993.0	-2.0
850 hPa Geo. Height (m)	1335	1305	-30
700 hPa Geo. Height (m)	2811	2769	-42
500 hPa Geo. Height (m)	5257	5198	-59
Surface Wind Speed (ms^{-1})	1.5	2.1	+0.6
850 hPa Wind Speed (ms^{-1})	7.9	7.9	0
700 hPa Wind Speed (ms^{-1})	9.6	10.4	+0.8
500 hPa Wind Speed (ms^{-1})	14.1	14.9	+0.8

The climatology of the two types was calculated and compared. The results are shown in Table I. As is to be expected, the surface temperature of the inversion cases are, on average, 5.0°C colder while temperatures at 850 hPa are warmer during inversion cases, by 4.2°C. As mentioned above, the increase in temperature of 1.5°C from the surface to 850 hPa in the no surface inversion cases supports the premise that elevated inversions exist, even when the inversion is not surface-based.

The surface pressure and geopotential height comparisons also yield results that are not unexpected, showing that surface pressure is 2.0 hPa lower during cases with no surface-based inversion. Lower surface pressure is often associated with stronger winds and more cloudiness; both parameter weaken a surface-based inversion. The geopotential height comparisons at the mandatory reporting levels are also consistently lower during no surface inversion cases.

Figure 1 shows the frequency distribution of surface wind direction during surface inversion and no surface inversion cases. The greater frequency of southerly winds during the no surface inversion cases indicates that the advection of warmer and more moist air is of importance. Frequently, this is accompanied by an increase in cloudiness; both inhibit the formation of surface-based inversions. The role of cloudiness on the winter temperatures in Fairbanks was investigated by Jayaweera et al. (1975).

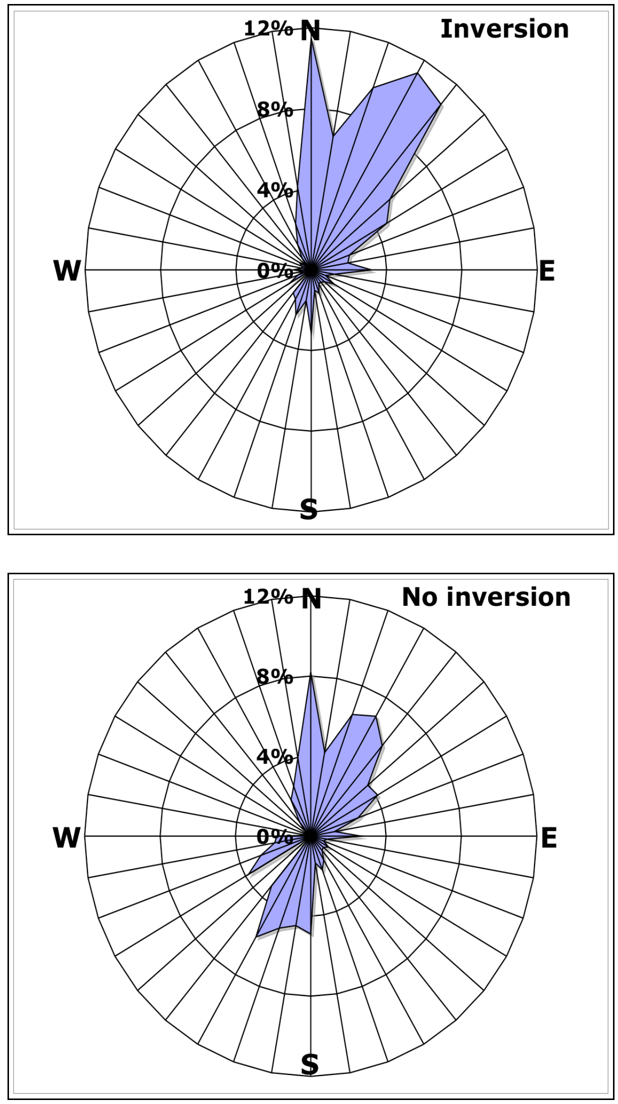

Figure 1. Frequency distribution of surface winds for surface inversion and no surface inversion cases

3.2 Characteristics and changes of the surface-based temperature inversion

Overall, the surface-based inversion exhibits the following mean characteristics, as shown in Table II.

Table II. Mean characteristics of the winter surface temperature inversion

ΔT	11.0°C
ΔP	65.0 hPa
Δz	520m
ΔT / Δz	2.1°C / 100m

The mean inversion characteristics place the top of the inversion at 930 hPa at a temperature of -10.8°C and a depth of 520m, but this masks the wide range of inversions that are actually observed varying in thickness from 30m to 3000m.

Over the 47-year record, the surface-based inversions Figure 2 shows the time series of the mean inversion depth at Fairbanks. A linear least-squares regression analysis shows that there has been a decrease in the mean depth of 212 m, which is statistically significant at a level of 99.9%.

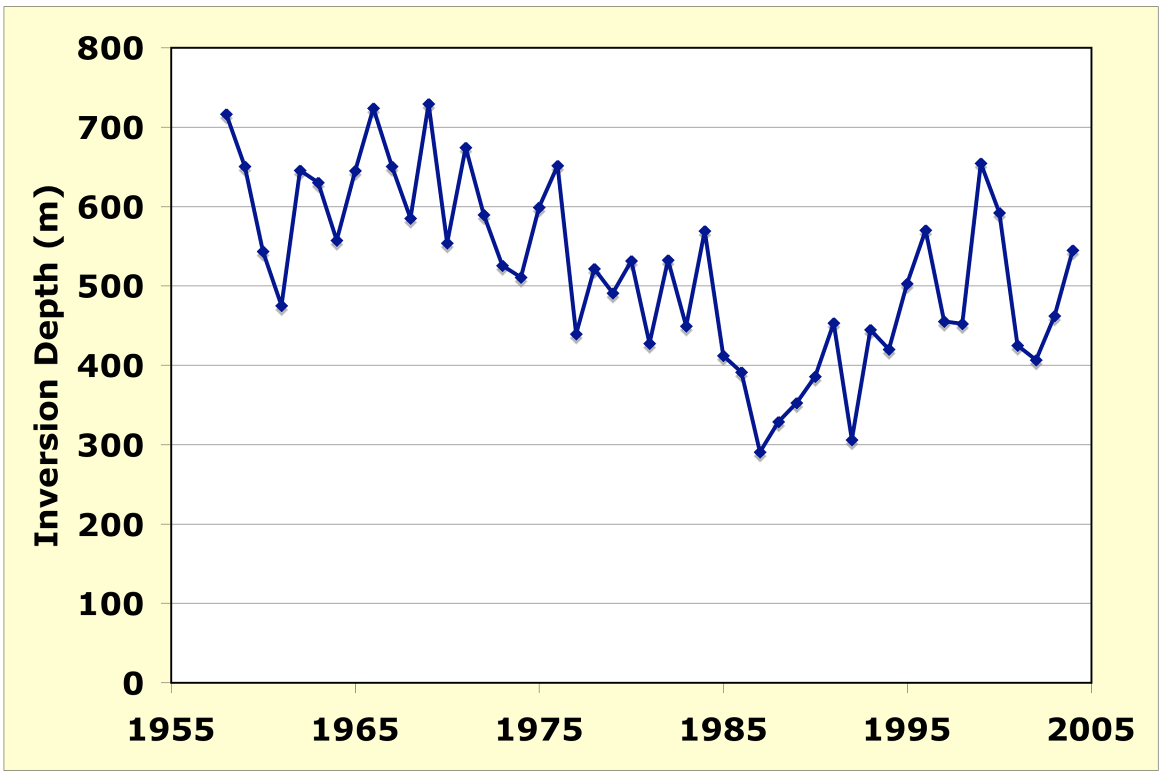

Figure 2. Time series of mean winter surface-based inversion depth

In addition to the decrease in the depth of the inversion, there has been an increase in the temperature at the top of the inversion of 2.5°C and a decrease of ΔT of 1.8°C. To fully investigate, one must investigate how the long-term temperature trends of the whole of the lower atmosphere could be affecting the characteristics of the inversion.

Figure 3 shows the temperature change from 1957-58 to 2003-04 based on the least-squares linear regression at the surface and the mandatory reporting levels up to 500 hPa. It can be seen that the increase in temperatures has occurred only during days with surface temperature inversions. The temperature increase is highest at the surface (4.2°C) and decreases with altitude. It is reduced to less that half of the surface value at the 700 hPa level.

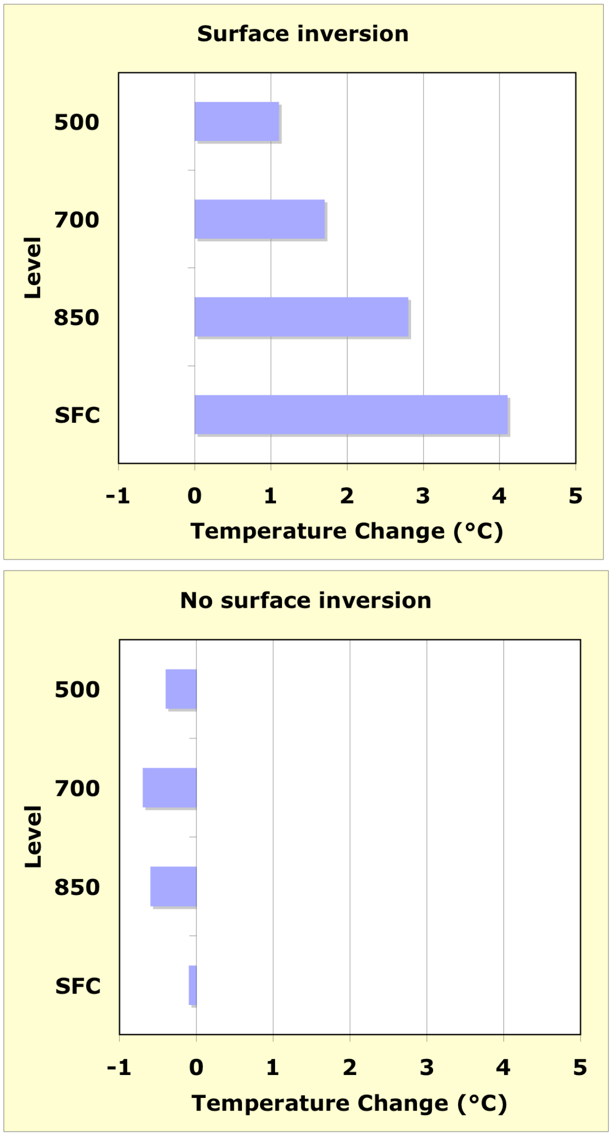

Figure 3. Change in mean winter temperature from 1957-58 to 2003-04 for surface inversion and no surface inversion cases.

It is to be noted that the temperature increase of 3.3°C stated in the abstract was based upon the mean seasonal temperatures as measured at a ground-based station and the temperature changes in Figure 3 are based upon the twice daily soundings. Only the surface increase is statistically significant at a confidence level greater than 95%. These results are in agreement with Curtis et al (2003) who showed the strongest positive temperature change during winter at the surface at Barrow, Alaska in a similar study of radiosonde climatology.

For the 'no surface inversion' cases, there has been a decrease in temperature, the magnitude of these decreases is however small. At the surface, 0.1°C were observed, and at the 700 hPa level the maximum of 0.7°C was observed.

With both the observed change in depth of the inversion and the observed change in the temperatures at various levels throughout the inversion affecting the ΔT of the inversion, a change in the mean gradient of the temperature inversion should be seen. Figure 5 illustrates the time series of the mean temperature gradient, which has increased by 0.7°C $100m^{-1}$, a trend significant at the 95% confidence level.

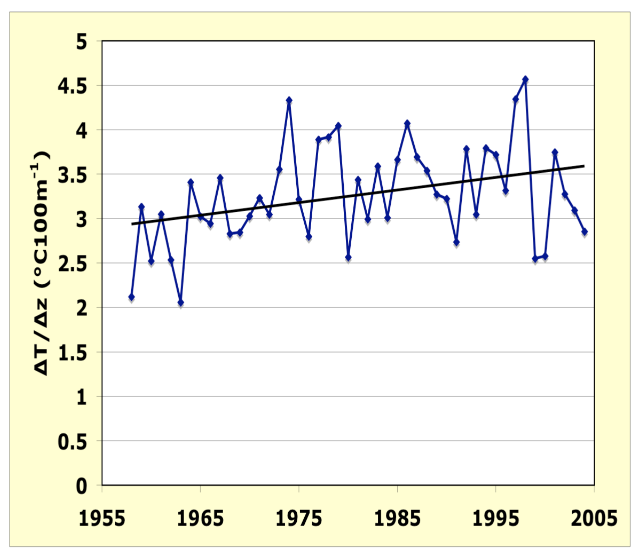

Figure 4. Time series of mean temperature gradient of the surface-based inversion

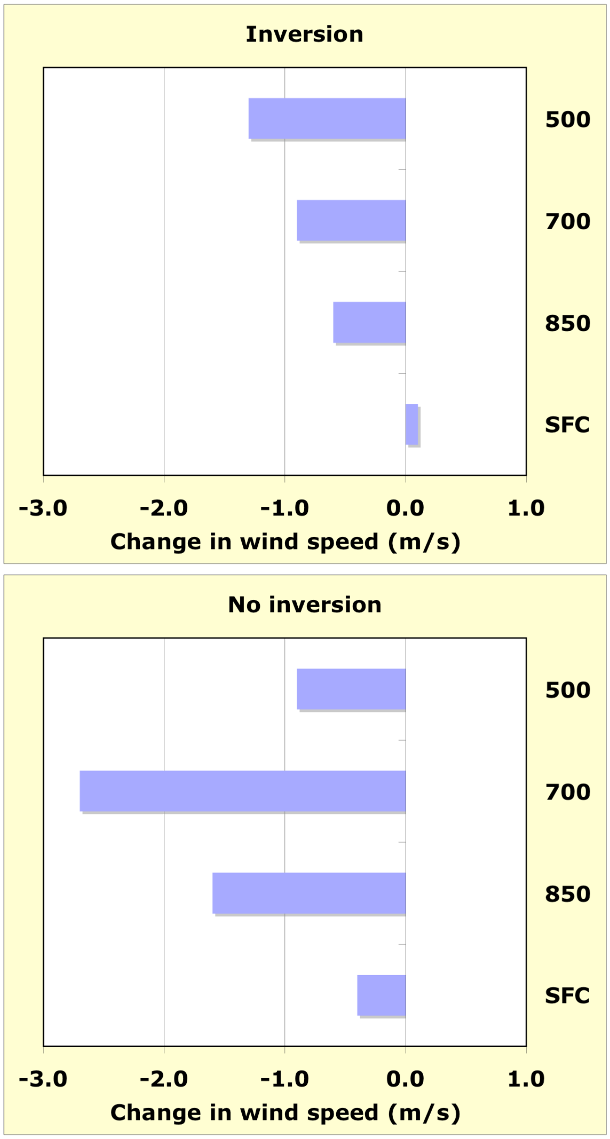

Figure 5. Change in mean winter wind speed from 1957-58 to 2003-04 for surface inversion and no surface inversion cases

The change in wind speeds at the surface and the levels up to 500 hPa are compared in Figure 5. The only observed slight increase in wind speed is seen at the surface during inversion cases and wind speeds have decreased at 500 and 700 hPa during inversion cases, but not as much as during non-inversion cases.

4. Discussion, Future Work and Conclusions

The role of the surface-based inversion in Fairbanks' air quality is an important factor to be considered, as Fairbanks has been classified as a serious non-attainment area for violations of national air quality standards. Changes in the frequency and nature of the inversions are of primary interest and importance for public health reasons and the specific relationship between the nature of different types of inversion and pollution levels in Fairbanks should be undertaken to determine the effect that the observed changes may have had, above and beyond the simple study of the frequency of occurrence. As a good time series of carbon monoxide measurements exist, pollution levels will be related to inversion strength.

Also, it appears that the observed increase in mean temperatures is closely related to the days where a surface based inversion is observed. The dramatic difference in the temperature trends of surface-based inversion vs. no surface-based inversion cases suggests that a change in the frequency of inversions might have a profound effect upon the observed warming trends seen during the winter in Fairbanks.

Future work is to include a more rigorous approach to the specific physical characteristics of the inversion itself and an in-depth study of the inversion frequency and intensity as a function of temperature, cloud amount, wind speed, and diurnal forcings.

Acknowledgments
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