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Characteristics of Low-level Temperature Inversions, Whitehorse Yukon Territory: 1956-2003

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Characteristics of low-level temperature inversions, Whitehorse Yukon Territory: 1956-2003

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Thesis submitted to the Faculty of Graduate and Postdoctoral Studies
in partial fulfillment of the requirements for the degree:
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ABSTRACT

Near-surface air temperature inversions are a common element of northern environments. Seasonal and inter-annual variations of low-level inversion characteristics were examined using 47 years of twice-daily radiosonde data from Whitehorse airport (1956-2003). Nocturnal low-level inversion events occurred throughout the year in 68% of the 0400h PST radiosonde ascents. Afternoon (1600h PST) inversion events, in contrast, were primarily a winter phenomena, limited to 24% of the readings between October and March, and were deepest and strongest during the winter months. Shorter, weaker, lower magnitude inversions appeared progressively more frequently during the 1974-2003 warming at Whitehorse. The impact (1956-2003) of regular low-level inversions on near surface temperatures in the Yukon River Valley is estimated to be an average annual reduction of -3.4°C. That is to say, in the absence of surface-based temperature inversion effects, the mean annual near-surface-temperature for Whitehorse (-0.7°C) would exceed 1°C, a temperature threshold at which permafrost could not be maintained. Overall inversion impact declined by about 1.5°C between 1956-1973 and 1974-2003.

ACKNOWLEDGEMENTS

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For Anne Johnson and Murriel Brownlee.

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1 INTRODUCTION

1.1 Background

Weather observation stations around the world play a critical role in our ability to understand climate and to forecast weather. In many areas, the density of station coverage is sufficient to make accurate and detailed climate observations. In other areas, such as the Canadian Arctic and Subarctic, station coverage is still quite uneven and a relative paucity of information and/or analyses exists.

In an internal report, commissioned by Environment Canada's Yukon Weather Centre (YWC) in 2006, long-term climate data provided by Environment Canada and the Yukon Forest Service were examined and summarised for Dawson, Mayo, Watson Lake and Whitehorse (Purves, 2006). Although records from these stations were not always continuous, they represented the longest (1942-the time of study) and most complete datasets for the Yukon Territory. Of these four stations, only the Whitehorse station had radiosonde data (1956-present).

Northwestern Canada has experienced the country's greatest warming in recent decades (ACIA, 2004). Accordingly, the data presented by Environment Canada reports strong evidence of climate warming in the Yukon Territory over the past 35 years. Significant cooling in mean daily minimum winter temperatures (-0.16°C/yr) is evident between approximately 1940 and 1970 at Whitehorse, followed by a period of marked warming (+0.18°C/yr) to date (Purves, 2006). When calculated as a mean annual temperature, the change between 1951-1980 and 1971-2000 is much less extreme at + 0.5°C (Northern Climate Exchange, 2006).

As a result of Whitehorse's location within a zone of discontinuous permafrost, where the average surface temperature is already quite close to zero (-0.7°C; National Climate Archive, Environment Canada, 2009), even a small change in temperature could have a widespread impact on permafrost distribution (Lewkowicz and Smith, 2004). Despite the critical role that climate change is likely playing in the presence and extent of permafrost in the Yukon Plateaus, temperature inversions as a factor in permafrost maintenance have often been overlooked. From the work presented here, it will become clear that the presence of a strong, surface-based inversion layer plays a critical role in regulating permafrost conditions in the valley bottoms of the Yukon Plateaus.

1.2 Justification for study and project objectives

Inversions are frequent in the Yukon Plateaus (Wahl et al., 1987). It can therefore be hypothesized that frequent, multiple inversion layers in the vertical air profiles of the Whitehorse Valley help to sustain an average annual temperature below 0°C. To date, only qualitative and generalised observations of inversion presence (e.g. Wahl et al., 1987) have been undertaken and no quantitative upper-air work is known.

This research explores the seasonal characteristics and the inter-annual trends of surface-based temperature inversions above Whitehorse, Yukon Territory between 1956 and 2003. The purpose is threefold: (1) to identify and extract seasonal and inter-annual trends within the data set; (2) to determine the association between the presence of atmospheric inversions and temperatures at the near surface; and (3) to assess the role of low-level inversions events on maintaining climatic conditions suitable for a permafrost environment in an area where the average annual temperature is close to 0°C.

The results of this study are significant for a number of follow up questions: How will ground surface temperatures, permafrost distribution, treeline, terrain stability, wildlife habitat, and anthropogenic infrastructure vary with a reduction or increase in the strength or regularity of inversions? How will humans and wildlife be required to adapt to these changes? And perhaps most importantly, based on historical trends and event characterisations, can changes in the strength and regularity of low-level atmospheric inversions be expected? Although the immediate scope of the research will not be able to answer these questions, the results will provide a base from which linkages can be made.

The literature review and study area are presented in Chapter 2. Chapter 3 details the extended analytical process. The results and conclusion of the research are summarized as an article in Chapter 4.

2 BACKGROUND INFORMATION AND LITERATURE REVIEW

2.1 History of Meteorological Observations in the Canadian Arctic

Initially, broad scale global weather monitoring efforts were restricted to locations of particular human interest (Northern Climate Exchange, 2006). Not surprisingly then, the history of meteorological observations in the Canadian Arctic is closely related to the history of exploration and war. However, stations were, and continue to be, sparsely distributed. Throughout the Canadian Arctic, climate records from monitoring stations are either short, of uncertain quality, or provide only limited spatial coverage (Serreze et al., 2000).

Although select short-term instrumental data were collected in some areas during expeditions and at outposts as far back as 1772, it was not until the first Polar Year in 1882-1883 that meteorological observations became an organized effort (Thomson, 1948). During the first Polar Year, three Arctic data stations were established: (1) Fort Rae, Great Slave Lake; (2) Fort Conger, Ellesmere Island; and (3) Kingua Fjord, Baffin Island, managed by Canada/Great Britain, the United States, and Germany, respectively (Patterson, 1940).

Meteorological data collected from the initial stations and the majority of later built pre-war stations were predominantly limited to surface-based readings. Regular upper-air data was not collected until 1941 and in many cases was considered discontinuous at best. The first upper air observation was made in 1822-1823, using a kite attached to a self-registering thermometer, and was limited to an ascent of 400 feet above the ground surface (Thomson, 1948). The second upper air observation was made more than a century later during the second Polar Year (1932-1933), using the same technique (Thomson, 1948).

With the outbreak of war in 1939, when weather observations became critical to flight path access, the value and deficiency of upper-air data from the Canadian North became apparent

(Thomson, 1948). Following the lead of the extensive radiosonde network that had been recently established in the United States and Alaska, the Canadian radiosonde was pushed to completion and mass production by 1941 (Thompson, 1948). During the same period, the Canadian Meteorological Division began regular surface observations at Whitehorse Airport, Yukon Territory (60°42'N, 135°07'W) (National Climate Archive, Environment Canada, 2009).

2.2 History of Climate Observations in Southwest Yukon and the Whitehorse Valley

2.2.1 Broad Scale Climate Observation for Southwest Yukon

Latitude, physiography, and proximity to the ocean all act to control the local climate of the Southwest Yukon. Located within the Boreal Cordillera Ecozone, and the Yukon Southern Lakes Ecoregion, the region is flanked by the St. Elias-Coast Mountains to the west, and a second interior barrier, the Cassiar-Pelly Mountains, to the east (Burn, 1994). The St. Elias Mountain range is the most tectonically active of the region, in some places exceeding 3500 m in elevation. As the dominant physical feature of the southwestern Yukon, this cordillera plays an important role in the local climate.

The arid Yukon Southern Lakes Ecoregion lies in the rainshadow of the St. Elias-Coast Mountains (Ecoregions of the Yukon Territory, part 2). Rain shadow effects - as a result of regional relief and substantial depletion of moisture from maritime air masses - are greater, the deeper and more sheltered the valley (Burn, 1994). Generally, precipitation ranges from 200-325 mm per year, of which up to 50% falls during summer (Environment Canada, 2007), making the climate of the Southwestern Yukon typical of a continental climate, where winters are cold and summers are warm and dry (Northern Climate Exchange, 2006). Snow is usually present from late October to mid-April in valley bottoms, and a month longer over higher terrain (Ecoregions of the Yukon, Part 2). Winter precipitation is derived solely from air masses that penetrate the mountains, while local convective activity and occasional storms from the Bering and Beaufort seas contribute during the summer (Wahl et al., 1987).

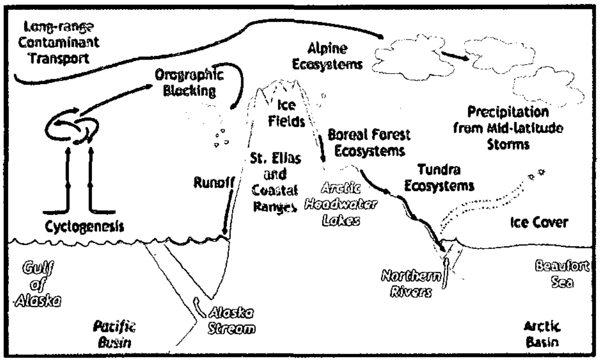


Figure 2.1: Schematic of topographic features of the southwest Yukon.

The St. Elias-Coast Mountains are the dominant feature of the southwest Yukon. The mountains intercept much of the moisture from air masses in the Pacific Ocean, contributing to the prevailing aridity of the adjacent forested regions. The accumulation of snow in the alpine areas also contributes to the hydrological dynamics of the Yukon (from Hik, 2000)

The orientation, relief, and location of the cordillera also facilitate a barrier to incoming weather from the Pacific Ocean, Gulf of Alaska, and to a lesser degree from the Arctic Ocean (Wahl et al, 1987; Burn, 1994) (Figure 2.1). In the winter, spring and early summer, the Yukon is dominated by arctic anticyclonic conditions (Wahl et al., 1987). In the late summer and autumn the region is occasionally penetrated by depressions occurring in the Gulf of Alaska (Wahl et al., 1987). Winds are common in major valleys and typically range from 30-50 km hr^{-1} (Ecoregions of the Yukon, Part 2). The windiest valleys are those with a northwest-southeast orientation (Northern Climate Exchange, 2006).

Continentality in the Yukon increases with distance from the Pacific coast (Burn, 1994). During the northern hemispheric winter, minimal solar heating and density driven cold-air drainage into valley bottoms combine to create extremely cold temperatures (Burn, 1994). The coldest temperatures are commonly recorded during November through January. However, high levels of snowcover often persist into February and March. The Whitehorse area is relatively snow-free between May and October, and changing albedos associated with snowmelt from March to May create sharp increases in the amount of absorbed solar energy (Wahl et al, 1987). Brief summers are generally warm in the valley bottoms (Burn, 1994). In valley bottoms within the Yukon, mean annual temperatures range between -1°C and -2°C in the southeast and -3°C to -4°C in the northwest (Ecoregions of the Yukon Territory, Part 2). Over higher terrain, mean temperatures can be several degrees higher as a result of atmospheric inversions (Ecoregions of the Yukon Territory, Part 2).

2.2.2 Local Temperature and Precipitation Observations for Whitehorse Valley

At the local scale, topography is an important climatic factor. In the Whitehorse Valley, slope angle and aspect all have fundamental effects on the amount of direct and diffuse radiation that is received at the ground surface. The aspect controls the time of day that the ground receives solar radiation and the slope controls the intensity of the incident radiation, both of which affect maximum and minimum temperatures (Wahl et al., 1987). In high relief terrain, shading of one hillslope by another can also influence the amount of solar radiation received (Cote, 2002). The areas directly around Whitehorse are characterized by deep, relatively narrow valleys separated by long, smooth topped ridges of relatively uniform heights of 1300 m (Bostock 1948).

Overall, the amount of short-wave solar radiation received at the horizontal surface decreases northward due to the lowered angle of incidence (Wahl et al., 1987). However, longer summer days moderate the annual radiation balance for Whitehorse. The result is a mean daily global solar radiation value higher than would be expected for its location (Wahl et al., 1987). Net radiation for Whitehorse is negative six months of the year, October to March inclusive (Wahl et al., 1987). Regular and persistent thick cloud cover over Whitehorse decreases the magnitude of the radiation deficit (Wahl et al., 1987).

Mean monthly temperatures, calculated from the means of the daily maximum and minimum temperatures at Whitehorse, range between -22°C and -13.3°C in January and between 7.7°C and 20.5°C in July (National Climate Archive, Environment Canada, 2009). The average annual amount of precipitation in the Yukon valley is low (267 mm), and is fairly evenly distributed between rain (163 mm) and snow (145 mm water equivalent). Mild mid-winter conditions occur more often than elsewhere in the Yukon as a result of the region's proximity to the Pacific Ocean (Northern Climate Exchange, 2006). Low levels of precipitation are the result of the rainshadow effect of the St. Elias-Coast Mountains. (Table 2.1)

Table 2.1: Climate of the Whitehorse Valley (1971-2000)

Mean annual temperature	-0.7 °C
Extreme maximum temperature (June)	34.4 °C
Extreme minimum temperature (January)	-52.2 °C
Mean daily maximum (July)	20.5 °C
Mean daily minimum (July)	7.7 °C
Mean daily average (July)	14.1°C
Mean daily maximum (January)	-13.3 °C
Mean daily minimum (January)	-22 °C
Mean daily average (January)	-17.7°C
Annual precipitation	267.4 mm
Annual rainfall	163.1 mm
Annual snowfall (water equivalent)	145 mm

Source: National Climate Archive, Environment Canada 2008

Note: Whitehorse A (ID:2101300) is located at 60°42.600'N 135°4.200'W at an elevation of 706.20 metres above sea level (masl)

2.3 Atmospheric Temperature Inversions

Atmospheric temperature inversions are a common condition of high-latitude climates. The phenomenon, when present, is identified by one or many layers of increasing air temperatures within the vertical air profile. Complex interactions between surface radiative cooling, subsidence, and warm air advection create a condition in which a layer of dense, cold air is overlain by a stratum of warmer air (e.g. Harris, 1981, 1982; Busch et al. 1982; Taylor et al., 1998). Geographic conditions which facilitate inversions include melting of surface-ice and snow, topographic variability and cold air drainage (e.g. Harris, 1981; Curry, 1983; Kahl, 1990; Taylor et al., 1998;).

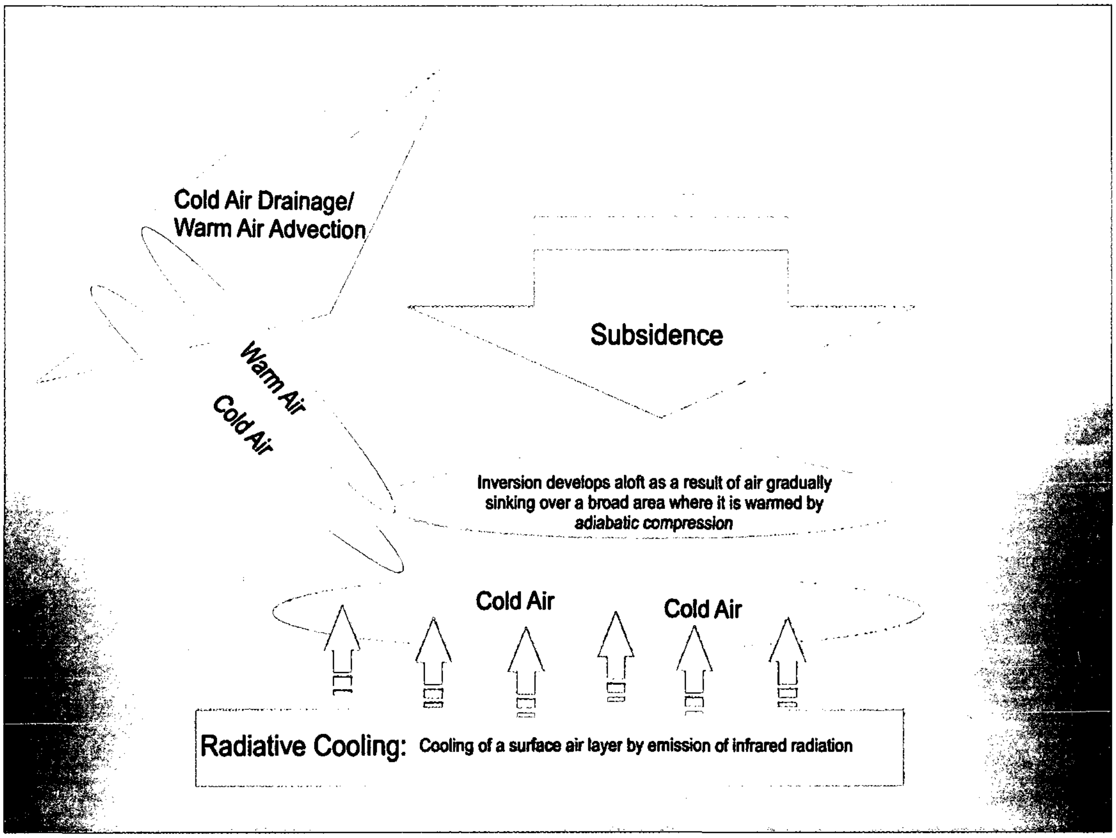


Figure 2.2 : Conditions and relationships between the multiple parameters of atmospheric inversions. (Prepared by author)

At high latitudes, inversions are driven primarily by radiation or subsidence. Radiation inversions are typically surface based, and commonly develop during clear, calm nights when there is little vertical mixing and a surface net radiation deficit (Bradley et al. 1992). Nocturnal inversions are normally short-lived and are usually destroyed by middle of the following day as a result of solar heating, although the time of destruction varies with latitude and season (Wahl et al., 1987). In contrast, subsidence inversions are caused by downward vertical motions in the atmosphere that are associated with anticyclonic conditions (Busch et al., 1982; Wark et al., 1998). In the Arctic, radiative inversions are the most common from January to April (Busch et al., 1982), when long arctic nights result in a deficit of solar radiation at the Earth's surface (Kahl, 1990).

Multiple inversion layers are frequently found in Arctic vertical air profiles (Belmont, 1957). However, it is the inversions in the layer nearest to the Earth's surface that have the greatest potential for impact on the terrestrial environment. Near-surface events are referred to as surface-based inversions.

> Note: For the purposes of this study, the term *surface-based inversion* refers to the occurrence of a positive temperature lapse rate within approximately 550 metres of the ground surface at Whitehorse (704 masl), in other words the inversion base is ≤ 1250 masl. The 550 metre threshold was chosen as a function of the top of the Mount Sima altitudinal transect, which extends to 1250 masl.

The presence of a strong surface based inversion layer causes energy to be trapped near the surface and ground temperatures to be decreased (Abdul-Wahab et al, 2004). It also acts as a determining factor in the dilution of atmospheric pollutants. Consequently, the correlation between surface temperatures and inversion properties is suggestive of the potential to use inversion characteristics (1) as indicators of climate change (Abdul-Wahab et al, 2004); (2) to project the cold-trapping of persistent organic pollutants, (Davidson et al., 2003); (3) to predict the location of ecological boundaries and wildlife habitat (Wahl, 1994); and (4) as is explored through this research, to predict the maintenance of a permafrost environment.

2.4 Permafrost

Permafrost is defined as ground (soil or rock) that remains cryotic, at or below a temperature of 0°C for two or more consecutive years (ACGR, 1988; Washburn 1979). Multiple factors (mean annual air temperature (MAAT), geothermal heat, past glaciation and climate, elevation, slope, aspect, vegetation/snow cover, and the presence or absence of water bodies) contribute to its presence, which causes its variable distribution. Globally, approximately 25% of landmass is underlain by permafrost. Within Canada, the land area affected by perennially frozen ground is approximately 50% (French, 1996).

2.4.1.1 Classification of Permafrost

Permafrost is classified in several ways: (1) in terms of the percentage area that is perennially frozen; and (2) by physical location (high latitude, alpine, subsea). Permafrost zones, referred to as continuous (90-100% permafrost), extensive discontinuous (50-90%), sporadic discontinuous (10-50%) and isolated patches (0-10%), indicate the percent of land underlain by permafrost (Heginbottom et al., 1995). The zones, which are often used in the context of high latitudes, can also be applied to alpine/mountain permafrost at high elevations in both high and low latitudes (Harris and Brown, 1982; King, 1986).

2.4.1.2 Global Distribution of Permafrost

Given that the geothermal heat at a location is generally constant, ground thermal regimes, and consequently permafrost conditions, are influenced primarily by differences in climate (French, 1996). As a result, permafrost zones are common at high latitudes and altitudes, generally transitioning from continuous permafrost through to sporadic and isolated patches. Where permafrost is patchy, it exists only under specific local microclimate conditions (Williams and Smith, 1989). Accordingly, it is not uncommon for permafrost to be aggrading or degrading in close proximity to the southern fringe of the sporadic discontinuous zone and in areas of isolated patches (Wahl et al., 1987).

2.4.2 Permafrost in the Whitehorse Valley, Yukon Territory

Permafrost in the Yukon ranges between sporadic discontinuous in the south and continuous in the north. Mountain permafrost is also present at higher elevations. (Figure 2.3) Within the

Yukon Southern Lakes Ecoregion, permafrost underlies less than one quarter of the landscape (Ecoregions of the Yukon Territory, Part 2).

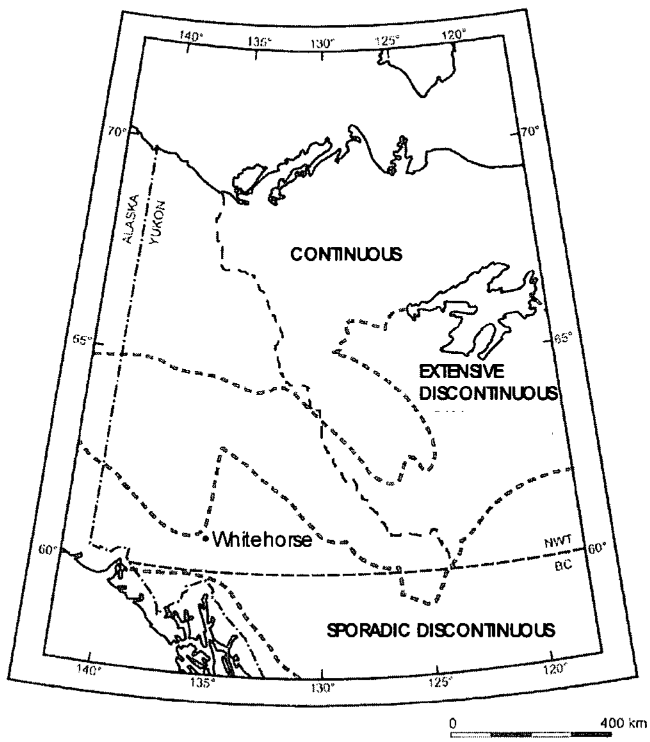


Figure 2.3: Permafrost distribution for Yukon Territory (after Heginbottom et al., 1995)

At Whitehorse, permafrost is limited to 2-3 meters deep, of which the upper 1.5 meters often becomes seasonally unfrozen (Burgess et al., 1982). Although spatially varied winter temperatures and relatively small amounts of winter precipitation do not catalyze the development and maintenance of permafrost in most of the Whitehorse Valley, cool summers at higher elevations can result in frozen ground at depth (Harris, 1983). Within valleys, permafrost limits are generally elevation-controlled (Lewkowicz and Ednie, 2004). In contrast to the perennially frozen ground that is sporadic in the valley bottom, alpine permafrost can be found up-slope (Burn, 1994).

2.5 Site Selection

The selection of the primary and secondary study sites was a function of logistics and data availability:

Primary Study Site: Whitehorse Airport, Yukon Territory

- Whitehorse Airport is one of about 1,000 stations in the world that collects information on the upper atmosphere using radiosonde data (Environment Canada – Yukon and Pacific Region, 2000). Within Canada, the core source of upper-air data is the radiosonde network, which consists of 31 stations (Environment Canada, 2002). Whitehorse Airport is the only radiosonde launch site in the Yukon Territory. The launch site is positioned approximately 60 m up-terrace of the valley bottom, at a surface elevation of 706.2 m asl (WMO Station: 71964) (Figure 2.4).
- Meteorological data from the Whitehorse Airport is available – relatively continuously – dating as far back as 1956.

Secondary Study Site 2: Mount Sima trail near Whitehorse, Yukon Territory

- The Mt. Sima trail altitudinal transect extends along a north-west facing slope of the Yukon Valley, located approximately 13 km south of the Whitehorse Airport. Ground surface and screen height temperature records from two stations at 1010 m asl (forest) and 1290 m asl (just above the treeline) have records available from 2004-2005.
- The proximity of the transect to Whitehorse Airport radiosonde launch site, and the fact that surface temperature data are collected hourly, 24-hours a day, makes the Mt. Sima trail a suitable site to examine the representativeness of twice-daily radiosonde data relative to the remaining 22 hours of the day.

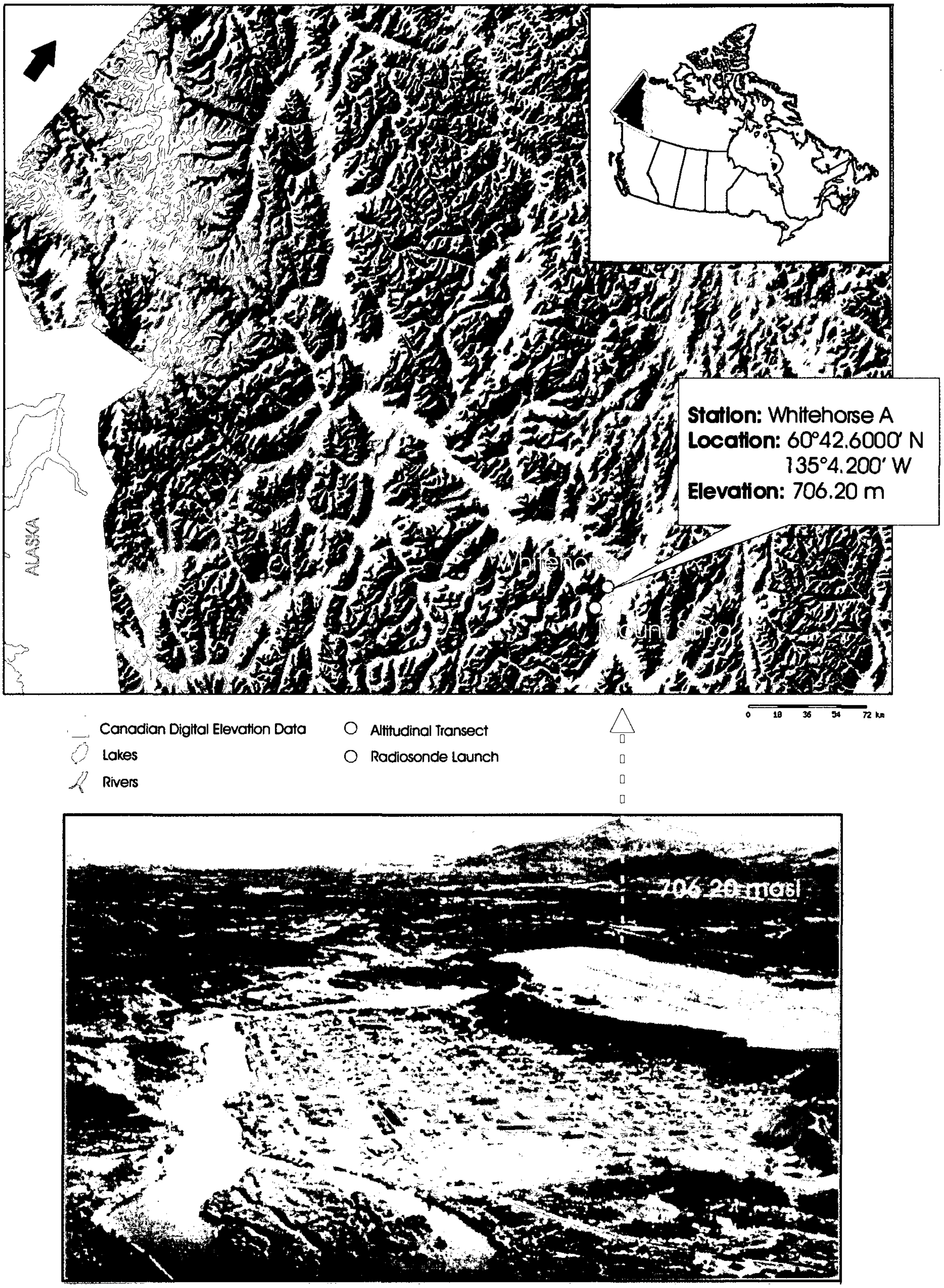


Photo: www.explorethenorth.com

Figure 2.4: Location of the radiosonde launch site (Whitehorse Airport) and altitudinal temperature transect (Mount Sima Trail) within the Yukon Plateaus. Map data source: Earth Science Data Interface, Geobase Location Files.

3 EXTENDED ANALYTICAL METHODOLOGY

3.1 Site Instrumentation

This research employed two types of quantitative instrumentation: (1) the radiosonde and (2) the Onset HOBO Pro temperature data logger.

Radiosonde

The radiosonde consists of a small, lightweight package of instruments which is suspended from a balloon. The balloon rises through the atmosphere at the approximate rate of 5 ms^{-1}. Temperature, elevation, pressure, humidity, and location are measured at semi-standardized intervals from the surface. Although the flight of the balloon is not strictly vertical, analysis at the synoptic scale can be performed without significant error (Abdul-Wahab et al, 2004). Temperature data obtained from the balloon sensors are accurate to ± 0.1°C (Meteorological Survey of Canada, 2008).

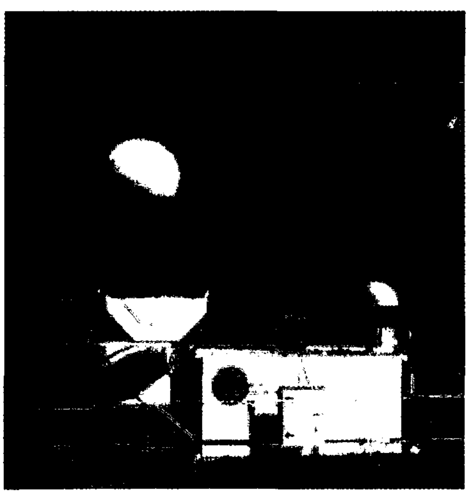


Figure 3.1: Whitehorse Airport Autosonde (Photo: Environment Canada, 2000)

Onset HOBO Pro

The Onset HOBO Pro is a temperature logger with internal and external thermistors. For the purposes of this study, two loggers were set up along an altitudinal transect at Mt. Sima. Ground surface temperature and screen height air temperature were logged hourly to an accuracy of ±0.2°C, over multiple years. Data were downloaded annually. However, only screen height air temperatures were analysed for this thesis.

Figure 3.2: Mounted data logger - Onset HOBO Pro (Photo: A.Lewkowicz, 2004)

3.2 Data Availability

This study analyses upper air data recorded at Whitehorse Airport (60°42'N, 135°04'W) between 1956 and 2003. The complete set of data (available between 1956 and 2007) could not be processed due to questions with regards to data quality, radiosonde launch frequency/timing, and the regularity at which the data were recorded within the vertical profile. The specific gaps identified for each of the data sources are discussed in greater detail in section 3.2.1.

3.2.1 Radiosonde Data

Upper air radiosonde data, consisting of vertical temperature profiles (accurate to ±0.1°C), dew-point temperature, wind speed and wind direction from the surface to a height of approximately 20-30 km, were obtained from three sources: (1) the National Climatic Data Center; (2) Environment Canada; and (2) the British Atmospheric Data Centre. In total, 16,908 days of data were evaluated.

Initial records (1956-1960) were obtained through the National Climatic Data Centre Archives, maintained by the National Oceanic and Atmospheric Administration **(NOAA).** Between 1956 and 1960, data were recorded on 1827 days. Missing data were identified for less than 0.3% of the scheduled soundings.

At the outset of data collection, soundings were recorded at 0300h PST (2300 zulu time) and 1500h PST (1100 zulu time) (1956 – June, 1957), following which, launch times were standardized to 0400h PST (2400 zulu time) and 1600h PST (1200 zulu time). Given the proportion of records (approximately 3%) recorded at 0300h and 1500h PST and the proximity of the initial launch time (1 hour) to the 45.5 years (July 1957-2003) following, no correction factor was calculated for the first 1.5 years. Likewise, no correction factor was calculated for the period of time prior to the switch from Yukon Standard Time (9 hours less than Coordinated Universal Time (UTC)) to Pacific Standard Time (-8 UTC) in 1983. Based on the diurnal cycle for inversions at Whitehorse (Figure 14), the shift should not have had a major impact.

Between 1961 and 2003, Environment Canada upper air data were recorded on 15,081 days, during scheduled radiosonde ascents at 0400h PST and 1600h PST. Missing data were identified for less than 3.5% of the data set. Particularly large data gaps occurred in 1990 (no data), in certain months in 1991 (May), 1994 (March), and 1997 (December), and in the morning soundings of February 1998 and December 2003.

Standard resolution radiosonde data were also obtained from the British Atmospheric Data Centre (BADC) - Met Office for 2004-2007, which in the end could not be included in the period of study for two reasons:

1. Due to lack of funding in 2004, the Whitehorse Airport radiosonde launch was decreased to once-daily (launched January – April at 1600h PST, and May – June at 0400h PST), following which, twice-daily launches were resumed at 1115h and 2315h PST. In relation to the diurnal inversion cycle for Whitehorse (see Figure 14), the results obtained for January 2004 onwards did not correspond to the other 47 years, and could not be effectively compared.
2. The frequency at which viable temperature and elevation data was recorded within the vertical profile did not align with the established criteria for identifying a 'surface based' (<1250 masl) inversion. Often the second workable record within the ascent was greater than 1250 masl.

3.2.2 Other Climate Data

Monthly air temperature averages for Whitehorse were obtained from the Environment Canada National Climate Archive (2008). The published monthly averages and annual average were used during the interpretation of relationships between changes in surface temperature and low-level inversion frequency and magnitude. Missing data occur in 1990, 1996, 1997 (all months) and select months in 1995 and 1998.

3.3 Representativeness of Upper Air Data

Inferences made from upper air data collected from daily and/or twice-daily radiosonde launches presented a potential problem for the calculation of inversion significance. It was not known whether twice daily atmospheric snapshots (i.e. 0400h/1600h) accurately represented the times of maximum and minimum inversion frequencies. The radiosonde's representativeness relative to the remaining hours of the day, was meant to be addressed through a direct comparison of the radiosonde data for a given year (i.e. 2004) to the Mt. Sima altitudinal transect data (measured hourly with Onset HOBO PRO temperature loggers) collected during the same year (i.e. 2004). However, given the reduced quality of the radiosonde data in the years following the installation of the data loggers (> Jan 2004), this direct comparison was not possible. It was still possible to assess the representativeness of the twice-daily sample in terms of frequency and magnitude of inversions as measured on the ground at Mt. Sima.

3.4 Objective Determination of Low-level Inversion Events

Data processing for this study was accomplished through the development of an inversion-detection algorithm in Python 3.0 (dynamic, object oriented programming). The algorithm served three key functions: (1) the removal of incomplete and/or erroneous altitudinal and atmospheric temperature records; (2) the objective determination of a surface-based inversion (positive lapse rate) within the first 550m of a given atmospheric profile; and (3) the computation and derivation of inversion characteristics.

3.4.1 Data Quality Control

During the extraction and characterisation of low-level inversion events, data points exhibiting insurmountable discrepancies/issues were removed both prior to and following the application of the inversion detection algorithm, which in total led to less than 3% of the records being removed. Three issues caused these problems. First, fewer than 1% of the records were removed prior to using the detection algorithm, as the result of missing temperature or elevation data. Second, a total of fewer than 2% of the records were removed following the application of the algorithm, in cases where inversion depth was less than 5 m, inversion strength was less than 0.3°C, or elevated CHI squared values suggested the extrapolation of the ground surface intercept deviated too significantly from the expected event. The logic behind these decisions is that the radiosonde rises at a rate of 5 m s^{-1} and the confidence interval of the balloon sensor is ± 0.1°C, respectively, meaning that values less than 5 m and 0.3°C could be the result of instrument error. Likewise, the determination of elevated CHI squared values suggests that the computer extrapolation of the ground surface intercept is unlikely to be representative of the actual conditions. In total, the temperature profiles of 16,908 days, between 1956 and 2003, could be evaluated.

3.4.2 Data Processing

Twice-daily (0400h and 1600h) radiosonde data were scanned upwards from the surface (700 m) to an elevation limit of 1250 meters using the detection algorithm. A surface-based inversion was recognized by the first occurrence of a positive lapse rate within the first 550 m of the atmospheric profile. The lower limit or surface-side value of the positive change defined the inversion base (≤ 550 m above the launch elevation) and the first subsequent reading where temperature decreased with altitude (at any point within the vertical full profile) delineated the top. From these values, inversion strength (the temperature difference across the inversion layer) and inversion depth (the elevation difference between the top and the base of the inversion layer) were calculated. Using the top of the inversion and the lapse rate in the curve above the point of inflection (the established top), the intensity of the inversion at the ground surface was projected, and the inversion magnitude (the cooling effects of the inversions at the ground surface) estimated. The impact of the inversion on near-surface temperatures was also estimated based on the frequency and magnitude of the inversions. The six steps of the algorithm are demonstrated below (Figures 3.3-3.6), using data collected on January 2, 1960 at 1600h. The script for the algorithm is included in Appendix D.

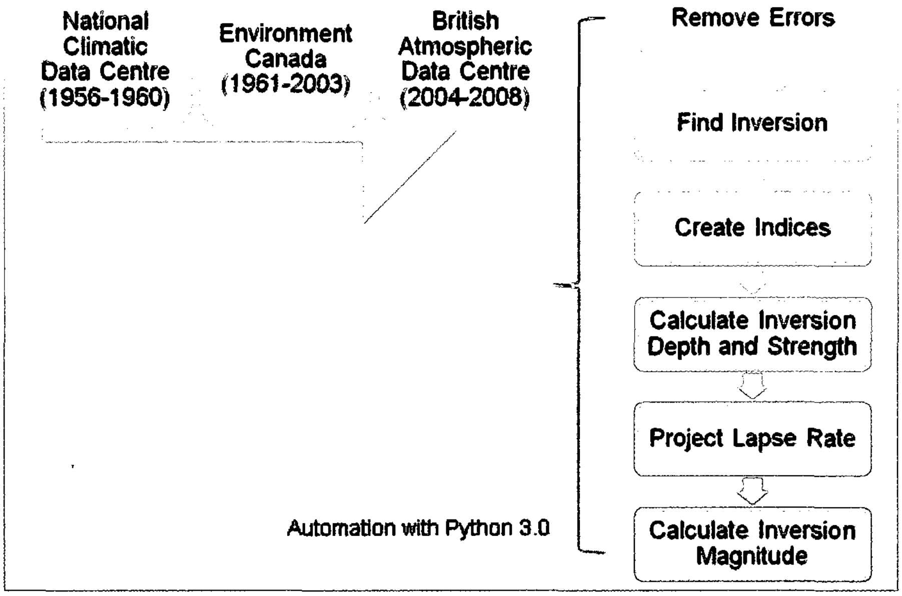


Figure 3.3: Flow diagram of the six step algorithm. Step 1 (Remove Errors); Step 2 (Find Inversion); Step 3 (Create Indices); Step 4 (Calculate Inversion Depth and Strength); Step 5 (Project Lapse Rate); Step 6 Calculate Inversion Magnitude).

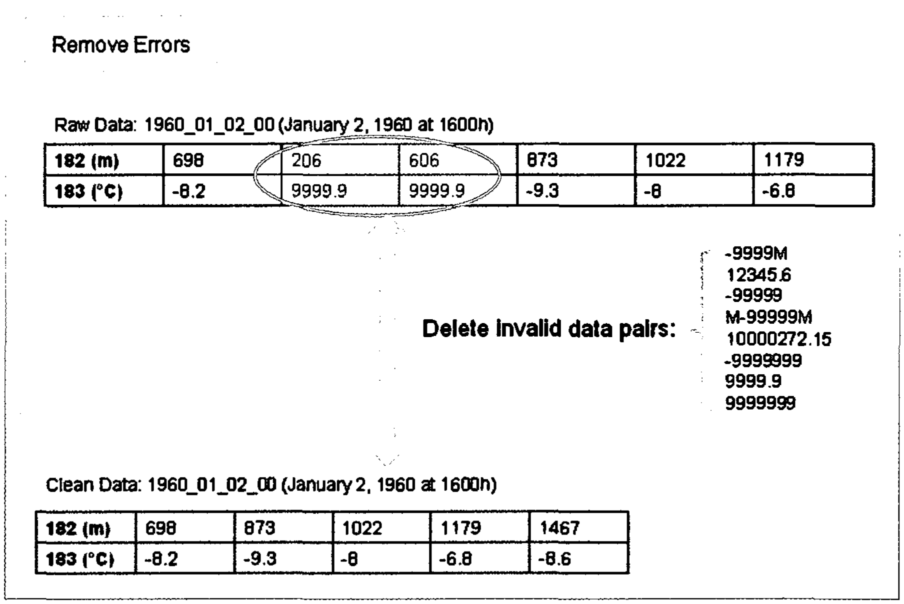


Figure 3.4: In Step 1 (Remove Errors), invalid altitude and/or temperature readings were located and parsed from the record.

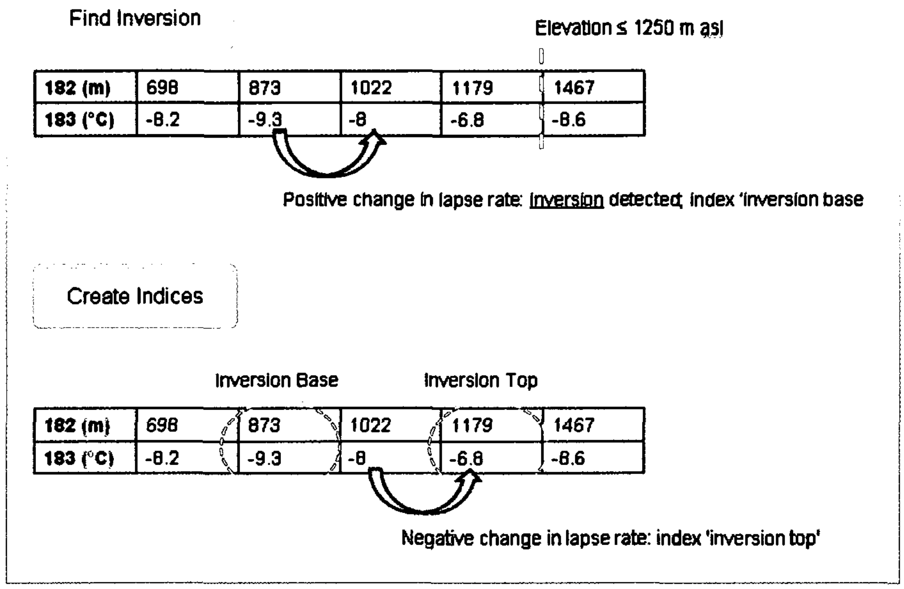


Figure 3.5: In Step 2 (Find Inversion), temperature data associated with elevation data ranging between 698 and 1250 m asl were scanned upwards for a positive change in lapse rate. If an inversion was detected, an index was created (Step 3) to define the inversion base and top.

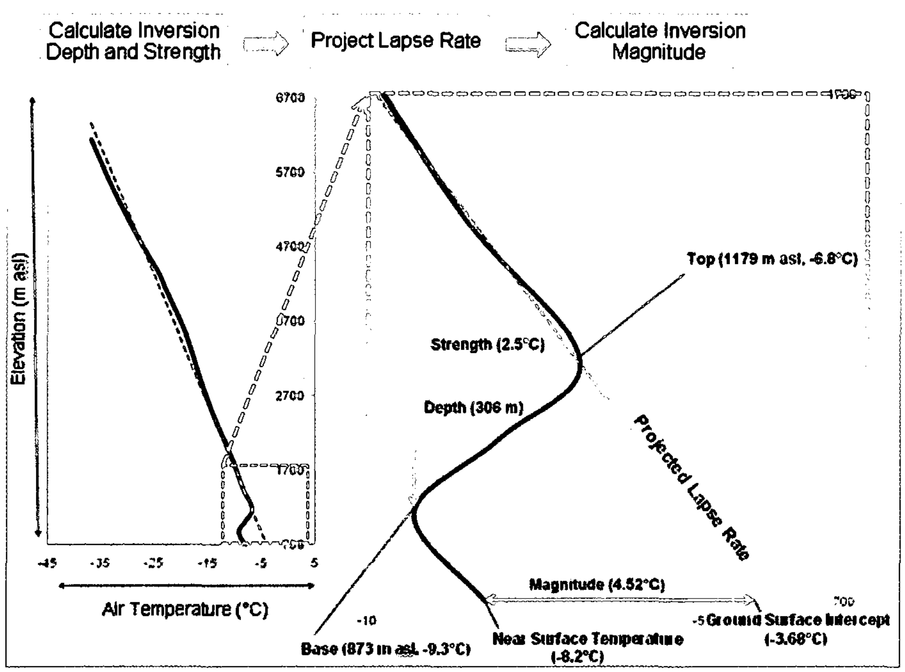


Figure 3.6: In Step 4 (Calculate Inversion Depth and Strength), data associated with the base and top of the inversion layer were used to calculate inversion strength and depth. In Step 5 (Project Lapse Rate), the ground surface intercept was established based on the projection of the lapse rate through the inversion top. In Step 6 (Calculate Inversion Magnitude), the magnitude was calculated by comparing the ground surface intercept that was calculated in Step 5 and the first temperature record of the radiosonde

The specific caculations performed to develop the parameters explained in Figures 3.3-3.6 are given below

3.4.2.1 Inversion Depth

Inversion depth is the difference in elevation between the top and base of the identified inversion layer.

3.4.2.2 Inversion Strength

Inversion strength is the difference in temperature between the top and base of the identified inversion layer.

3.4.2.3 Inversion Frequency

The annual and cumulative frequencies of surface-based inversions were calculated based on the number of surface-based inversions relative to the number of legitimate soundings per month:

$$F_{SBI} = N_{SBI}/N_{sound}$$

The frequency equation is a derivation of Kahl et al.'s work (1996) which describes inversion regularity as a function of $F_{SBI} = N_{SBI}/N_{inv}$ and $F_{all} = N_{inv}/N_{sound}$, where F: frequency, N: count, SBI: surface-based inversions, inv: for inversions, sound: soundings, and all: all inversion events.

3.4.2.4 Inversion Magnitude

The magnitude of the inversion was used to estimate the cooling effects of low-level inversions to regional surface temperatures. To calculate magnitude, the ground surface temperature was predicted from the supra-inversion lapse rate and the difference between the projected surface temperature and the actual surface temperature calculated.

3.4.2.5 Inversion Impact

The impact of the inversion is an estimation of how much cooler it is at the near-surface as a result of inversion presence.

Inversion impact was calculated annually using the following equation:

$$\frac{[(\mathrm{InversionFrequency}_{0400h})(\mathrm{InversionMagnitude}_{1600h})] + [(\mathrm{InversionFequency}_{1600h})(\mathrm{InversionFrequency}_{1600h})]}{2}$$

3.4.3 Quality Assurance/Quality Control

The accuracy of the computer-based algorithms used to extract the inversion data was vetted using conventional review. For each data set, temperature inversions (or lack thereof) were identified manually on the 1st and the 15th of each month. When an inversion was present, the complete suite of statistical analysis was performed. A 0% error was calculated from the manual review of the automated filter.

4 CHARACTERISTICS OF LOW-LEVEL TEMPERATURE INVERSIONS, WHITEHORSE, YUKON TERRITORY: 1956-2003

Manuscript planned for submission to: Journal of Applied Meteorology and Climatology

Authorship: A. Lovatt and A.G. Lewkowicz

Responsibilities: A. Lovatt carried out the data analyses under the supervision of A.G. Lewkowicz and drafted the text which was edited by A.G. Lewkowicz.

CHARACTERISTICS OF LOW-LEVEL TEMPERATURE INVERSIONS, WHITEHORSE, YUKON TERRITORY: 1956-2003

ABSTRACT

Near-surface air temperature inversions are a common element of northern environments. Seasonal and inter-annual variations of low-level inversion characteristics were examined using 47 years of twice-daily radiosonde data from Whitehorse airport (1956-2003). Nocturnal low-level inversion events occurred throughout the year in 68% of the 0400h PST radiosonde ascents. Afternoon (1600h PST) inversion events, in contrast, were primarily a winter phenomena, limited to 24% of the readings between October and March, and were deepest and strongest during the winter months. Shorter, weaker, lower magnitude inversions appeared progressively more frequently during the 1974-2003 warming at Whitehorse. The impact (1956-2003) of regular low-level inversions on near surface temperatures in the Yukon River Valley is estimated to be an average annual reduction of -3.4°C . That is to say, in the absence of surface-based temperature inversion effects, the mean annual near-surface-temperature for Whitehorse (-0.7°C) would exceed 1°C, a temperature threshold at which permafrost could not be maintained. Overall inversion impact declined by about 1.5°C between 1956-1973 and 1974-2003.

1 INTRODUCTION

In the Yukon Plateau region, the supposition that air temperatures decrease with altitude is frequently incorrect (Harris, 1981). Multiple inversion layers in the vertical air profiles of the Whitehorse Valley are common and are known to factor into the maintenance of average annual subzero surface temperatures (Wahl et al., 1987). However, other than qualitative and generalised observations of inversion presence, little quantitative analysis of upper-air data has been undertaken.

Identified as early as 1914 in kite ascents over Siberia (Brooks (1931) in Serreze et al. (1992)), temperature inversions are characterized by one or many layers of increasing air temperatures within the vertical air profile, and are generally the result of complex interactions between surface radiative cooling, subsidence, and warm air advection (e.g. Harris, 1981, 1982; Busch et al. 1982; Taylor et al., 1998). At high latitudes, such as those of the Yukon Territory, inversions are driven most often by radiation and/or subsidence.

Radiation inversions are characteristically surface-based, and commonly develop during clear, calm nights when there is little vertical mixing and a surface net radiation deficit (Bradley et al. 1992). Nocturnal radiation inversions are normally short-lived and are usually destroyed by the middle of the following day as a result of solar heating, although the time of destruction varies with latitude and season (Wahl et al., 1987). Subsidence inversions, in contrast, are caused by downward vertical motions in the atmosphere that are associated with anticyclonic conditions (Busch et al., 1982; Wark et al., 1998).

Although multiple types of inversion layers are frequently found in Arctic vertical air profiles (Belmont, 1957), it is the inversions in the layer nearest to the Earth's surface that have the greatest potential to impact the surface. The presence of a strong surface-based inversion layer is known to cause lower ground temperatures and higher concentrations of atmospheric pollutants (Abdul-Wahab et al, 2004). Accordingly, within the literature, inversion presence has been linked to indicators of climate change (Abdul-Wahab et al, 2004), the cold-trapping of persistent organic pollutants (Davidson et al., 2003), and the prediction of ecological boundaries and wildlife habitat (Whal, 1987). In this work, inversion characteristics and frequency will be used to predict the maintenance of a permafrost environment.

The aim of this paper is to explore the characteristics and frequency of surface-based temperature inversions above Whitehorse, Yukon Territory between 1956 and 2003. The purpose of the investigation is threefold: (1) to identify and extract seasonal and inter-annual trends within the data set; (2) to determine the association between the presence of atmospheric inversions and the temperature at the ground surface; and (3) to assess the role of low-level inversions events on maintaining climatic conditions suitable for a permafrost environment in an area where the average annual temperature is close to 0°C.

2 DATA SOURCES AND METHODS

Radiosonde data were collected twice-daily (0400h and 1600h local time - 2400 and 1200 zulu time) at Whitehorse Airport (60°42'N, 135°04'W; 706.2 masl; WMO Station: 71964 – Whitehorse Airport). As far back as 1956, these data provide a snap-shot of the vertical air profile on a specific date and at a specific time, and can be used to described climatological conditions such as atmospheric temperature (accurate to ±0.1°C), dew-point temperature, wind speed and wind direction from the surface to approximately 20-30 km.

The complete set of available radiosonde data was obtained from three sources: (1) the National Climatic Data Center (1956-1960); (2) Environment Canada (1961-2003); and (3) the British Atmospheric Data Centre (2004-2007). However, questions regarding data quality, radiosonde launch frequency/timing, and the regularity at which the data were recorded within the vertical profile required that approximately 3.5% of the soundings be removed from the analysis. Particularly large data gaps occurred in 1990 (no data), certain months in 1991 (May), 1994 (March), and 1997 (December), and in the morning soundings of February 1998 and December 2003. Standard resolution radiosonde data obtained for 2004-2007 were also removed from the study for the following reasons: (1) Due to lack of funding in 2004, the Whitehorse Airport radiosonde launch was decreased to once-daily (launched January – April at 1600h PST, and May – June at 0400h PST), following which, twice-daily launches were resumed at 1115h and 2315h PST. In relation to the diurnal inversion cycle for Whitehorse (see Figure 14), the results obtained for January 2004 onwards did not correspond to the other 47 years, and could not be effectively compared; and (2) The frequency at which viable temperature and elevation data was recorded within the vertical profile did not align with the established criteria for identifying a 'surface based' (<1250 masl) inversion. Often the second workable record within the ascent was greater than 1250 masl.

Data processing for this study was accomplished through the development of an inversion-detection algorithm in Python 3.0 (dynamic, object oriented programming). The algorithm served three key functions: (1) the removal of incomplete and/or erroneous altitudinal and atmospheric temperature records; (2) the objective determination of a surface-based inversion (positive lapse rate) within the first 550 m of a given atmospheric profile; and (3) the computation and derivation of inversion characteristics.

Using the detection algorithm, twice-daily (0400h and 1600h) radiosonde data were scanned upwards from the surface (700 masl) to an elevation limit of 1250 masl. The 550 m above launch elevation threshold was chosen as a function of the top of the Mount Sima altitudinal transect, which extends to 1250 masl. A surface-based inversion was recognized by the first occurrence of a positive lapse rate within the first 550 m of the atmospheric profile. The lower limit or surface-side value of the positive change defined the inversion base (≤ 550 m above launch site) and the first subsequent reading where temperature decreased with altitude (at any point within the vertical full profile) delineated the top.

Using the values for the temperature and altitude parameters at the top and the base of the inversion, inversion strength (the temperature difference across the inversion layer) and inversion depth (the elevation difference between the top and the base of the inversion layer) were calculated. Using the top of the inversion and the lapse rate in the curve above the point of inflection (the established top), the intensity of the inversion at the ground surface was projected, and the inversion magnitude (the cooling effects of the inversions at the surface) estimated. (Figure 1)

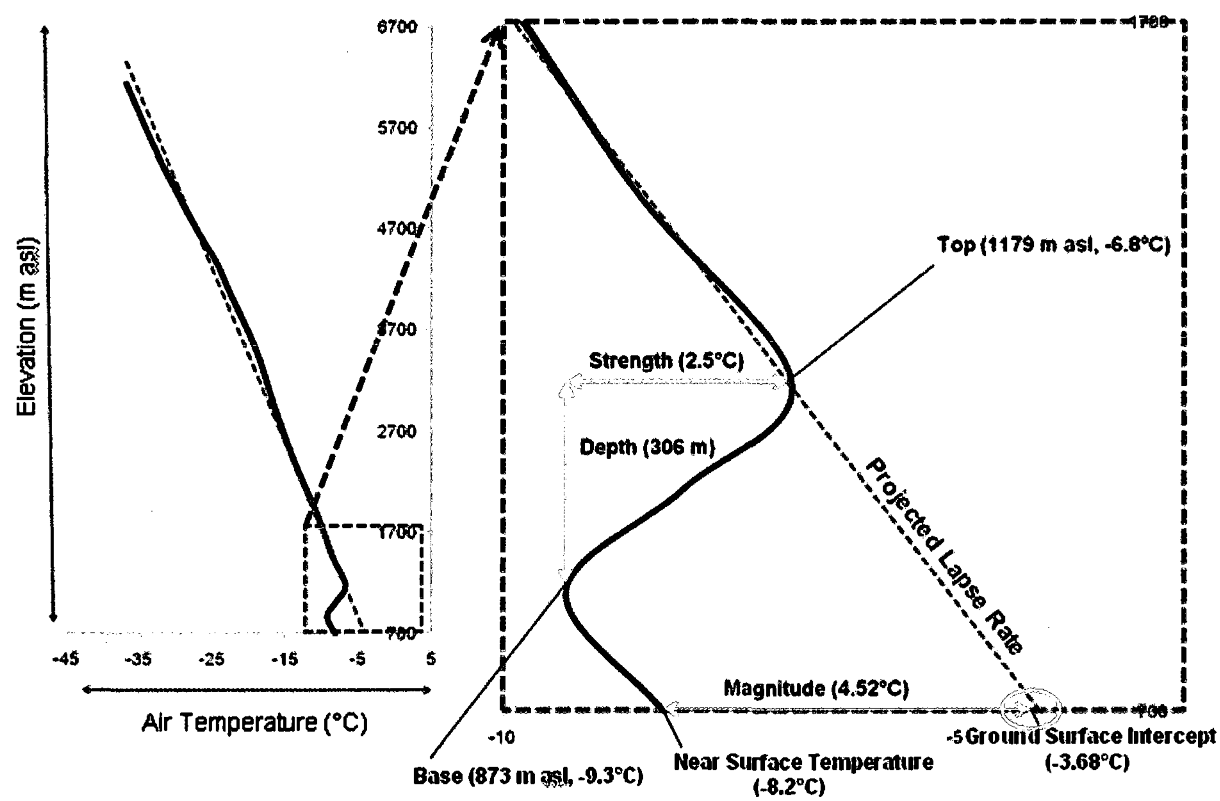


Figure 1: Schematic definition of inversion parameters based on the 1600h temperature profile, at Whitehorse Airport, Yukon Territory on January 2, 1960. Developed from radiosonde launch data (960_01_02_00).

From the data, two other parameters were extracted: inversion frequency and the projected impact of the inversion on near-surface temperatures. The annual and cumulative frequency of surface-based inversions was calculated based on the number of surface-based inversions relative to the number of legitimate soundings per month($F_{SBI} = N_{SBI}/N_{sound}$). The frequency equation is a derivation of Kahl et al.'s (1996) work which describes inversion regularity as a function of $F_{SBI} = N_{SBI}/N_{inv}$ and $F_{all} = N_{inv}/N_{sound}$, where F: frequency, N: count, SBI: surface-based inversions, inv: for inversions, sound: soundings, and all: all inversion events. The impact of inversions on near-surface temperatures (the approximation of how much cooler the near surface is as a result of inversion occurrence) was estimated as a function of frequency and magnitude, with the following equation:

$$\frac{[(\text{InversionFrequency}_{0400h})(\text{InversionMagnitude}_{1600h})] + [(\text{InversionFequency}_{1600h})(\text{InversionFrequency}_{1600h})]}{2}$$

The use of this equation assumes that the timing of the radiosonde ascents represent the maximum and minimum likelihood and magnitude of inversions, or that they are equally distant (positively and negatively) from the mean values so that their average is close to the mean. The validity of this assumption is discussed later.

During the extraction and characterisation of low-level inversion events, data points exhibiting insurmountable discrepancies/issues (defined below) were removed during and following the application of the inversion detection algorithm, which in total led to less than 3% of the records being removed. Overall, three issues were identified. First, fewer than 1% of the records were removed prior to using the detection algorithm, as the result of missing temperature or elevation data. Second, a total of fewer than 2% of the records were removed post-characterisation due to an inversion depth less than 5 m, or inversion strength < 0.3°C, or the calculation of elevated CHI squared values for the extrapolation of the ground surface intercept.

The logic behind these decisions is that the radiosonde rises at a rate of 5 m s^{-1} and the confidence interval of the balloon sensor is ± 0.1°C, respectively, meaning that values less than 5 m and 0.3°C might be the result of instrument error. Likewise, the determination of elevated CHI squared values suggests that the computer extrapolation of the ground surface intercept is unlikely to be representative of the actual conditions. In total, the temperature profiles of 16,908 days, between 1956 and 2003, could be evaluated.

Accuracy for the computer-based algorithms was vetted using manual review. Temperature inversions (or lack thereof) were identified manually on the 1st and the 15th of each month. When an inversion was present, the complete suite of analyses was performed manually. This review of the automated filter showed a 0% error, indicating that the automated algorithm could be used with confidence.

3 RESULTS AND DISCUSSION

3.1 Summary of general observations for inversion characteristics

At the daily scale, surface-based inversions at Whitehorse occurred 46% of the time, with average inversion frequencies ranging from 52% in October to >80% in December and January for the 0400 radiosonde sounding, and from less than 2.2% between April and September to almost 80% in December and January at 1600h. Of the total number of inversions identified, approximately three quarters (74%) originated during the night and were likely radiative in nature. Standard deviations for nocturnal inversion frequency (± 14% annually) were greatest during the shoulder seasons (as defined in section 3.3) and through the summer months. The inverse was true for the afternoon inversion (± 7% annually). Average inversion depth, strength and magnitude exhibited similar inter-annual patterns: reaching maxima during the winter and minima during the summer. Between November and February average values for depth (506 m), strength (6.2°C), and magnitude (9.8°C) exceeded the yearly averages by almost 50%, 70%, and 60%, respectively. Similarly, maximum daily variability for depth, strength, and magnitude occurred in winter, when the standard deviation values were equal to almost half of the annual mean values. (Table 3)

3.2 Inter-annual trends in inversion characteristics

3.2.1 Yearly data split by periods of general cooling and warming

Climate normals are calculated averages that are updated at the end of each decade. The most recent climate normals available for Whitehorse Airport are 1961-1990 and 1971-2000. The published normal for mean annual air temperature at Whitehorse Airport increased from -1.0°C between 1961 and 1990, to -0.7°C between 1971 and 2000 (Environment Canada, 2008). This fits with the identified pattern of general cooling between 1943 and 1973, and strong warming from 1974 through to the present day at Whitehorse (Purves, 2006), which is thought to have been accelerated by a dramatic North Pacific climate shift known to have taken place in 1976 and to have coincided with a change in the phase of the Pacific Decadal Oscillation (PDO) (Hartman and Wendler, 2005).

For the current study, the mean annual air temperature was calculated for 1974-2003 (inclusive), which corresponds to the last 30 years of radiosonde data (1974-2003) and allowed for comparison between a period of known warming (1974-2003) and a period of general cooling (1956-1973) (Figure 2). 30-year averages for each of the inversion parameters are plotted relative to the 1956-1973 averages in Figure 3.

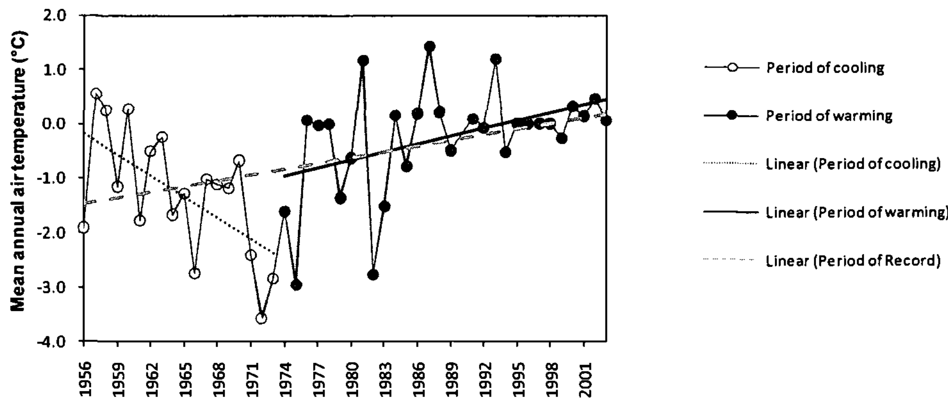
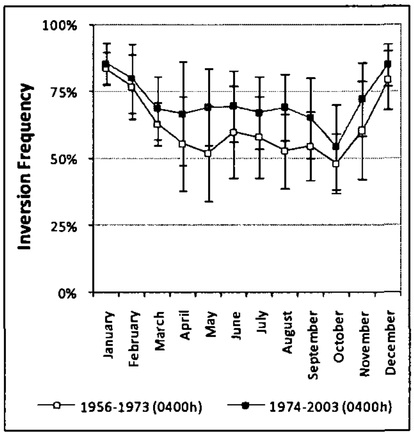


Figure 2: Mean annual air temperatures at Whitehorse for the period of radiosonde analysis (1956-2003)

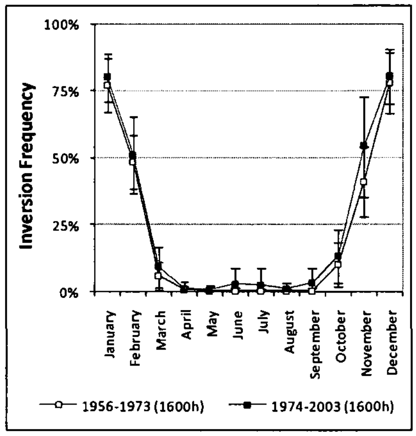
0400h

1600h

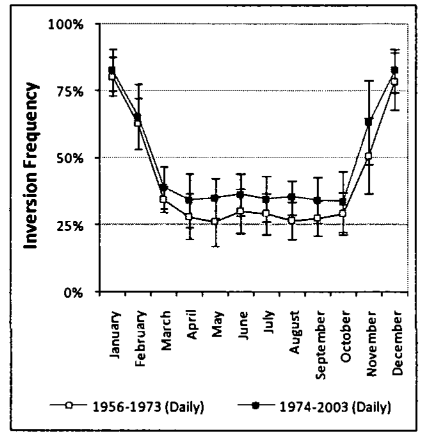
Daily



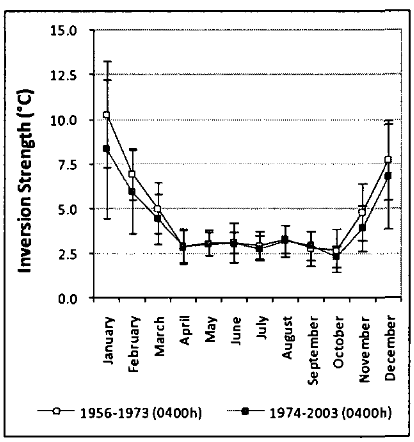
3.1 - Comparison of average inversion frequency (at 0400h) by month during periods of surface cooling (1956-1973) and warming (1974-2003)



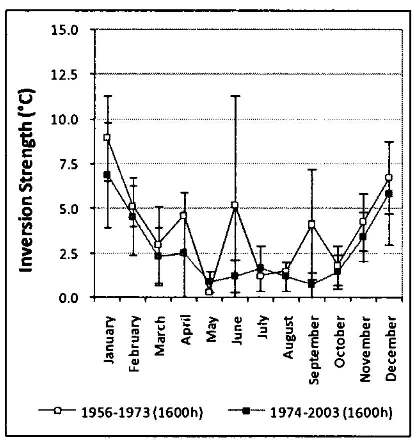
3.2 - Comparison of average inversion frequency (at 1600h) by month during periods of surface cooling (1956-1973) and warming (1974-2003)



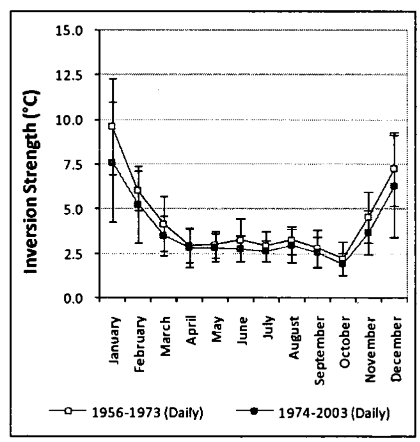
3.3 - Comparison of average inversion frequency (at the daily-scale: 0400h + 1600h) by month during periods of surface cooling (1956-1973) and warming (1974-2003)



3.4 - Comparison of average inversion strength (at 0400h) by month during periods of surface cooling (1956-1973) and warming (1974-2003)



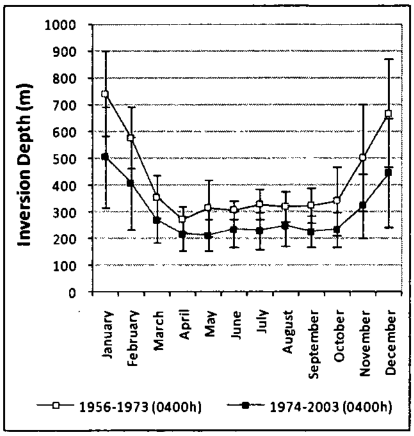
3.5 - Comparison of average inversion strength (at 1600h) by month during periods of surface cooling (1956-1973) and warming (1974-2003)



3.6 - Comparison of average inversion strength (at the daily-scale: 0400h + 1600h) by month during periods of surface cooling (1956-1973) and warming (1974-2003)

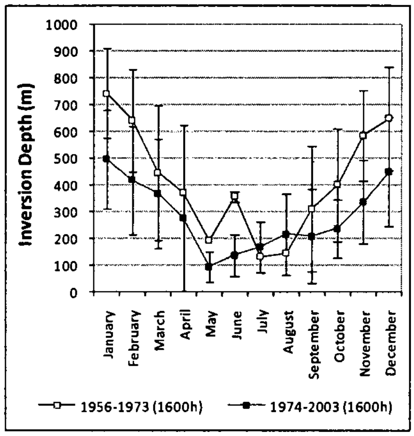
Figure 3 – Comparison of inversion characteristics during surface cooling (1956-1973) and warming periods (1974-2003)

0400h



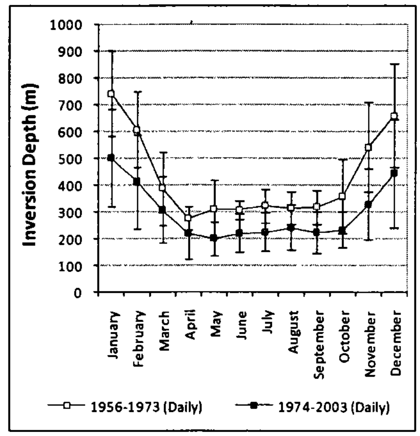
3.7 - Comparison of average inversion depth (at 0400h) by month during periods of surface cooling (1956-1973) and warming (1974-2003)

1600h

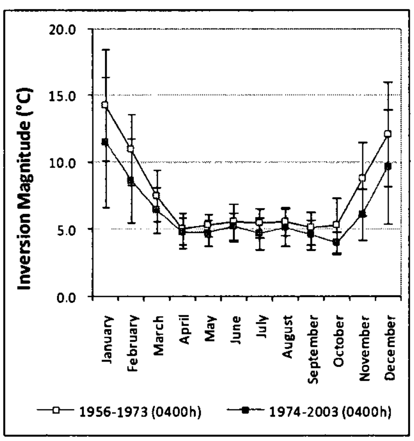


3.8 - Comparison of average inversion depth (at 1600h) by month during periods of surface cooling (1956-1973) and warming (1974-2003)

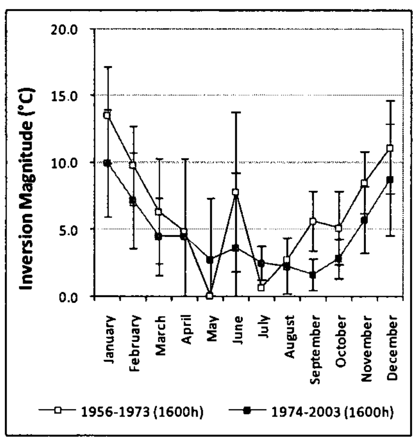
Daily



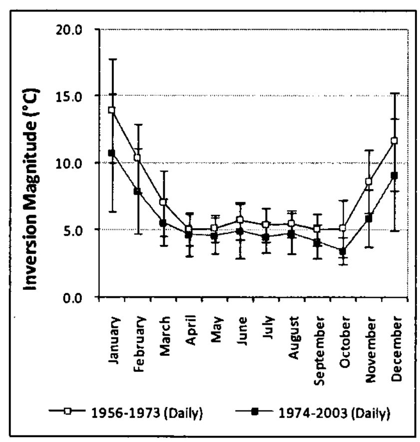
3.9 - Comparison of average inversion depth (at the daily-scale: 0400h + 1600h) by month during periods of surface cooling (1956-1973) and warming (1974-2003)



3.10 - Comparison of average inversion magnitude (at 0400h) by month during periods of surface cooling (1956-1973) and warming (1974-2003)



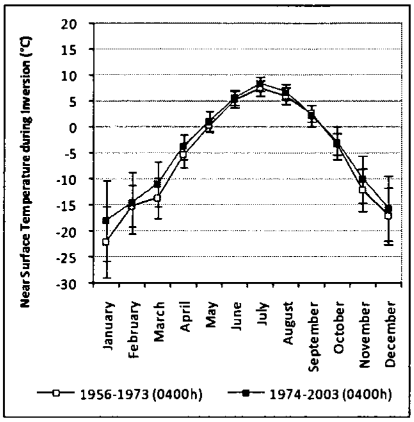
3.11 - Comparison of average inversion magnitude (at 1600h) by month during periods of surface cooling (1956-1973) and warming (1974-2003)



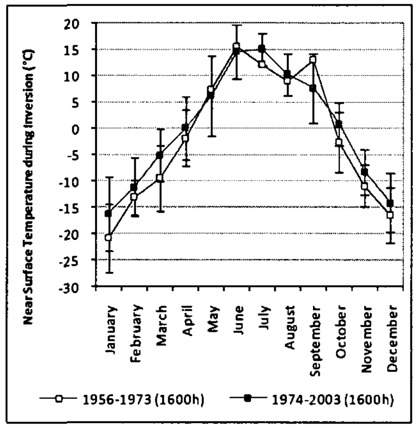
3.12 - Comparison of average inversion magnitude (at the daily-scale: 0400h + 1600h) by month during periods of surface cooling (1956-1973) and warming (1974-2003)

Figure 3 (continued) – Comparison of inversion characteristics during surface cooling (1956-1973) and warming periods (1974-2003)

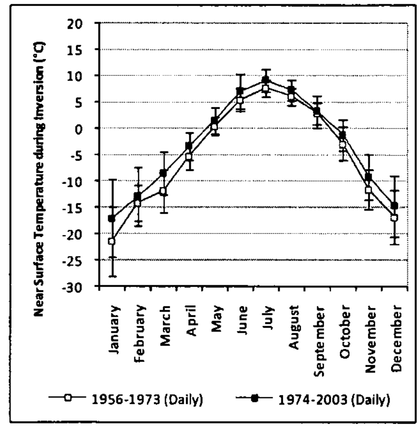
0400h | 1600h | Daily



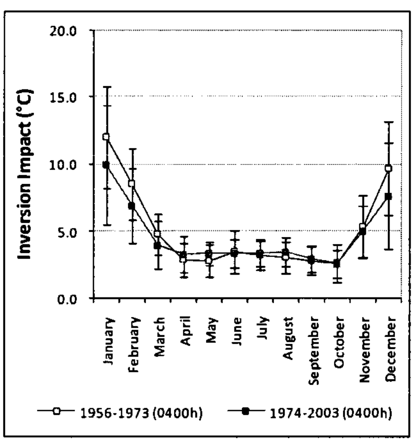
3.13 - Comparison of average near-surface temperatures on inversion days (at 0400h) by month during periods of surface cooling (1956-1973) and warming (1974-2003)



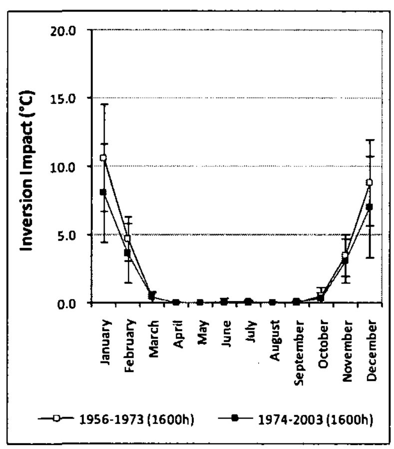
3.14 - Comparison of average near-surface temperatures on inversion days (at 1600h) by month during periods of surface cooling (1956-1973) and warming (1974-2003)



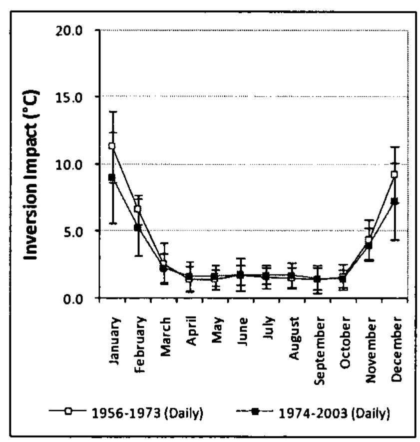
3.15 - Comparison of average near-surface temperatures on inversion days (at the daily-scale: 0400h + 1600h) by month during periods of surface cooling (1956-1973) and warming (1974-2003)



3.16 - Comparison of average inversion impact (at 0400h) by month during periods of surface cooling (1956-1973) and warming (1974-2003)



3.17 - Comparison of average inversion impact (at 1600h) by month during periods of surface cooling (1956-1973) and warming (1974-2003)



3.18 - Comparison of average inversion impact (at the daily-scale: 0400h + 1600h) by month during periods of surface cooling (1956-1973) and warming (1974-2003)

Figure 3 (continued) – Comparison of inversion characteristics during surface cooling (1956-1973) and warming periods (1974-2003)

Considerable change in inversion parameters appears to have occurred between the 1956-1973 cooling and the 1974-2003 warming periods. While these conclusions are not considered statistically significant due to a violation of the assumption of the linear model, which assumes that the residuals are identically and independently distributed, the consistency of the changes suggests that the patterns in the data can be used with reasonable confidence. Inversion frequency increased, especially at 0400h and particularly during the spring and summer months. Inversion depth decreased most of the winter at both 0400h and 1600h, with large reductions continuing into most of the summer months. Inversion strength declined in the fall and winter at 0400h and 1600h, but changed less in summer. Inversion magnitude and the impact of the inversion at the surface exhibited the same pattern, with large decreases at both launch times in most non-summer months. Finally, the near-surface temperature during inversions increased, especially in winter.

Over the entire year, results for the 0400h radiosonde launch indicate average decreases in inversion depth (-128 m), strength (-0.4°C), and magnitude (-1.5°C), accompanied by average increases in surface temperatures on inversion days (+1.3°C) and inversion frequency (+8%). Trends are magnified in the 1600h data for all parameters but frequency: depth, strength, and magnitude decreased by -173 m, -0.5°C, and -1.8°C, respectively, while surface temperatures and inversion frequency increased by +1.5°C and +3%. On the whole, between 1956-1973 and 1974-2003 inversions became shallower and weaker, but more frequent.

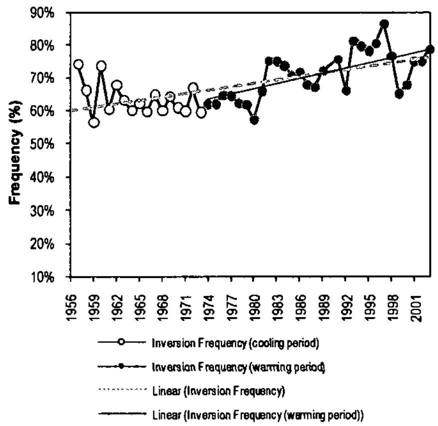
3.2.2 Overall yearly data

Taken as a whole (1956-2003), the time-series plots indicate downward trends for inversion magnitude, strength, and depth, and upwards trends for inversion frequency and near-surface air temperatures on inversion days (Figure 4). The average amount of change calculated for the 47-year period is based on the linear trendline, which appears to be a reasonable model, despite the possibility that residuals are not identically and independently distributed. Consistent slope changes are identified for both the 0400h and 1600h soundings and at the daily-scale (Table 2). The step-like change that occurs in 1981 has not been vetted, and may be the result of instrument error, the source of which has not been confirmed.

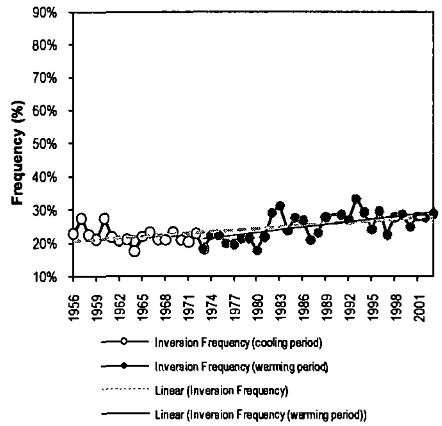
On the daily-scale, inversion frequency increased by 12% on average, accompanied by near-surface temperature increases for days with inversions on the order of +5°C. In contrast, inversion depth, strength, and magnitude all decreased by an average -335 m, -2°C, and -4.5°C, respectively. Similar results were obtained for the 0400h sounding, with increases estimated as +16% for inversion frequency and +5°C for near-surface temperatures during an inversion. Decreases are recorded on the order of -300 m for depth, -2°C for strength, and -4°C for magnitude. Related trends are evident for the 1600h launch, but the degree of change was greater: decrease in depth of -460 m, decrease in strength of -3.4°C, decrease in magnitude of -6°C and increase in near-surface temperature during inversion of +8°C. The only variable that changed less in the afternoon than in the morning is inversion frequency (increase of +7.5%).

The impact of inversion presence at the valley bottom is estimated as -4.8°C during the morning (0400h radiosonde launch) and -2.1°C in the afternoon (1600h radiosonde launch). Assuming the average of these two to represent an average for the full 24 hours, the overall impact of inversion presence on annual air temperature for the entire study period is calculated as a cooling of -3.4°C. This has not remained constant over the record: an overall decrease in impact equal to approximately 1.5°C is identified between 1956 and 2003 (Figure 4).

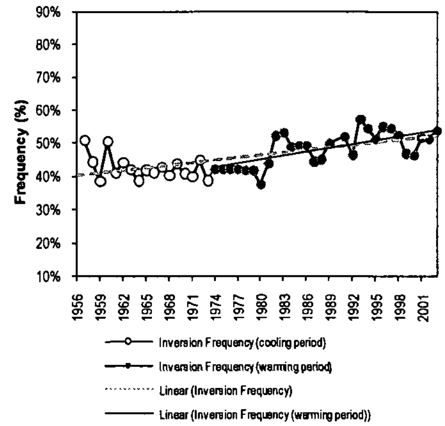
0400h | 1600h | Daily



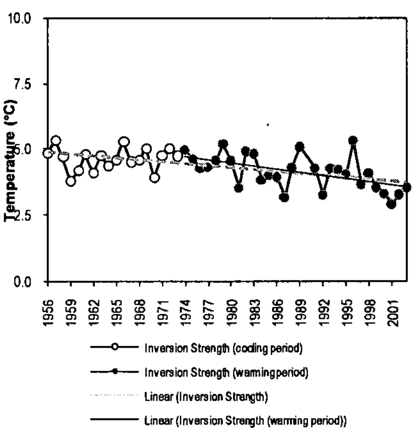
4.1 – Average inversion frequency calculated annually (1956-2003) for the 0400h launch



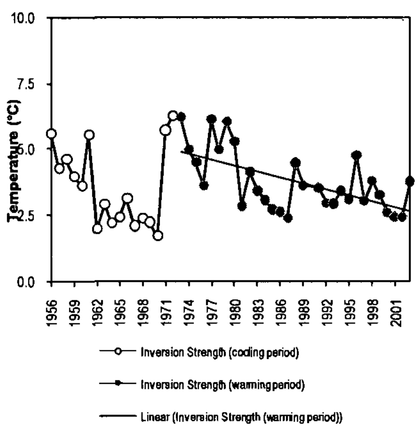
4.2 – Average inversion frequency calculated annually (1956-2003) for the 1600h launch



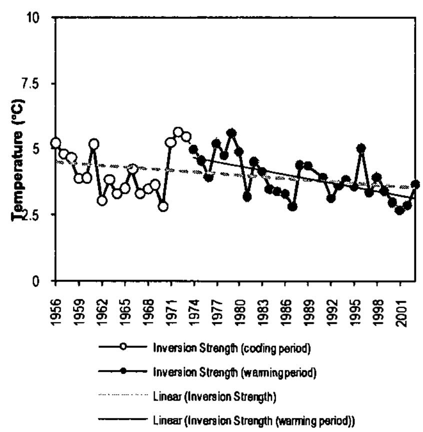
4.3 – Average inversion frequency calculated annually (1956-2003) at the daily-scale (0400h + 1600h)



4.4 – Average inversion strength calculated annually (1956-2003) for the 0400h launch



4.5 – Average inversion strength calculated annually (1956-2003) for the 1600h launch

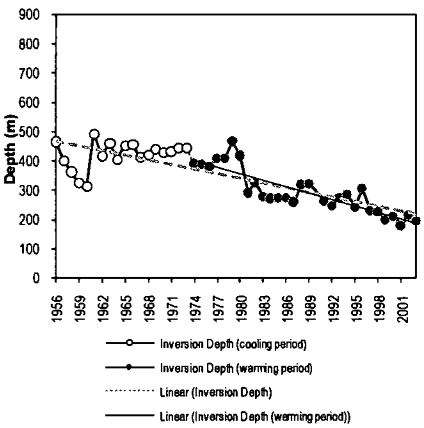


4.6 – Average inversion strength calculated annually (1956-2003) at the daily-scale (0400h + 1600h)

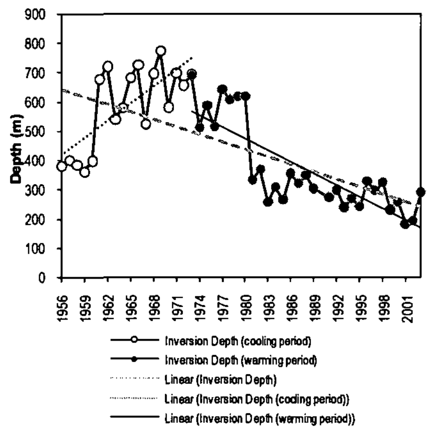
Figure 4 – Time series analysis of annual inversion characteristics (1956-2003)

Note: Linear regressions are assumed to be significant at p = 0.05 (see Table 2). Violations of the assumptions of the linear model have not been checked.

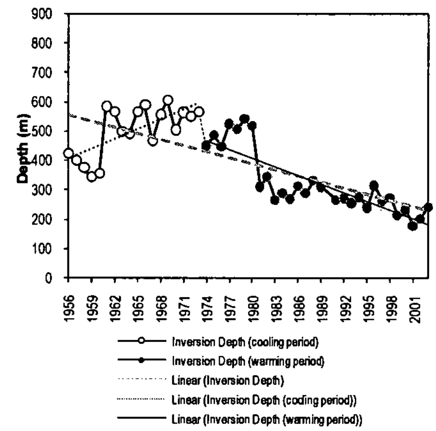
0400h | 1600h | Daily



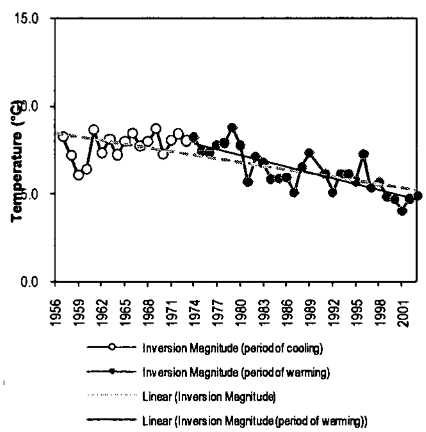
4.7 – Average inversion depth calculated annually (1956-2003) for the 0400h launch



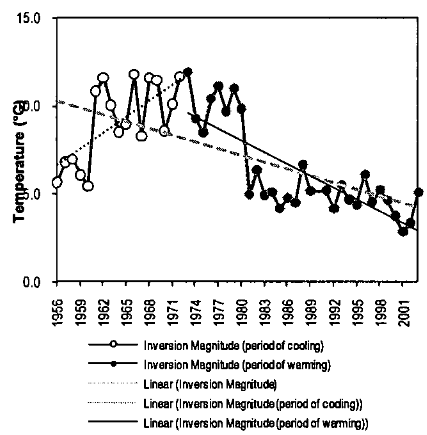
4.8 – Average inversion depth calculated annually (1956-2003) for the 1600h launch



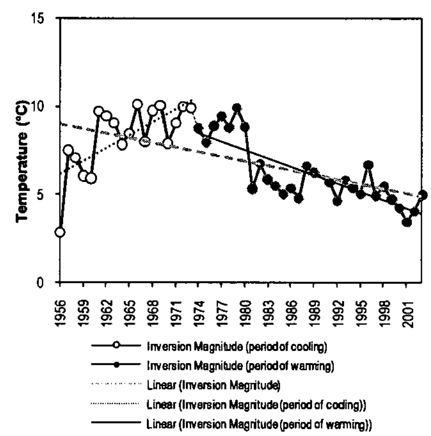
4.9 – Average inversion depth calculated annually (1956-2003) at the daily-scale (0400h + 1600h)



4.10 – Average inversion magnitude calculated annually (1956-2003) for the 0400h launch



4.11 – Average inversion magnitude calculated annually (1956-2003) for the 1600h launch

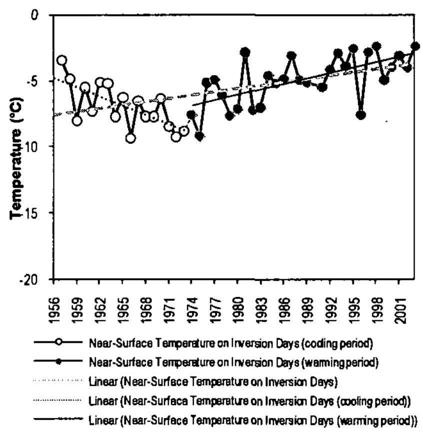


4.12 – Average inversion magnitude calculated annually (1956-2003) at the daily-scale (0400h + 1600h)

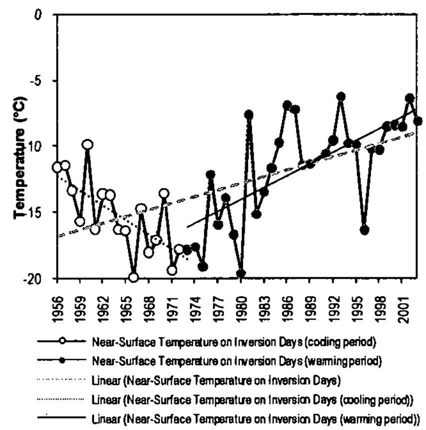
Figure 4 (continued) – Time series analysis of annual inversion characteristics (1956-2003)

Note: Linear regressions are assumed to be significant at p = 0.05 (see Table 2). Violations of the assumptions of the linear model have not been checked.

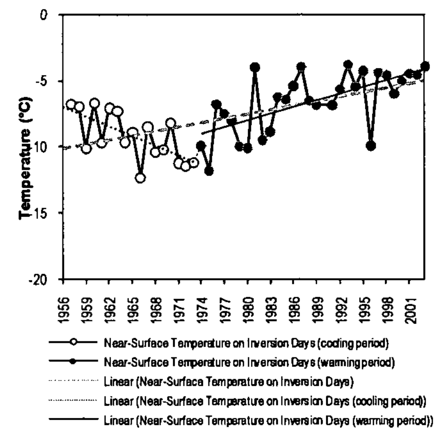
0400h | 1600h | Daily



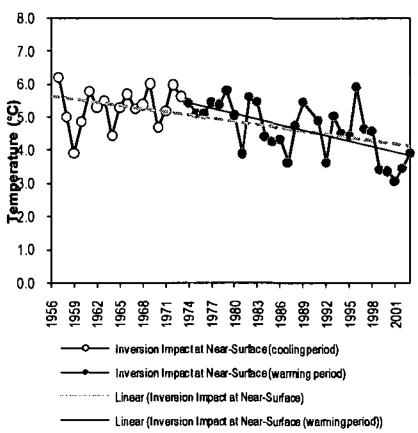
4.13 – Annual average near-surface temperature for inversion days (1956-2003) identified during the 0400h launch



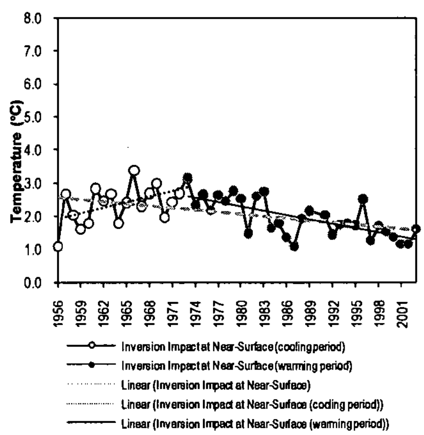
4.14 – Annual average near-surface temperature for inversion days (1956-2003) identified during the 1600h launch



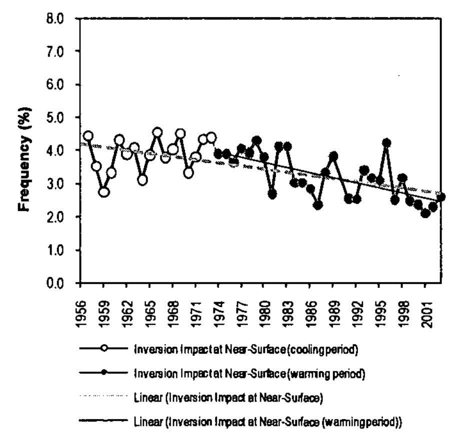
4.15 – Annual average near-surface temperature for inversion days (1956-2003) identified at the daily-scale (0400h + 1600h)



4.16 – Average of inversion impact on near-surface temperatures calculated annually (1956-2003) for the 0400h launch



4.17 – Average of inversion impact on near-surface temperatures calculated annually (1956-2003) for the 1600h launch



4.18 – Average of inversion impact on near-surface temperatures calculated annually (1956-2003) at the daily-scale (0400h + 1600h)

Figure 4 (continued) – Time series analysis of annual inversion characteristics (1956-2003)

Note: Linear regressions are assumed to be significant at p = 0.05 (see Table 2). Violations of the assumptions of the linear model have not been checked.

Table 1 – Regression statistics for time series of annual inversion characteristics (1956-2003)

		Period of Cooling (1956-1973)					Period of Warming (1974-2004)					Period of Record (1956-2004)				
		R Squared	Regression Significance F	Coefficents (X variable 1)	Standard Error (X variable 1)	P-value (X variable 1)	R Squared	Regression Significance F	Coefficents (X variable 1)	Standard Error (X variable 1)	P-value (X variable 1)	R Squared	Regression Significance F	Coefficents (X variable 1)	Standard Error (X variable 1)	P-value (X variable 1)
0400h	Frequency (%)	0.162	0.110	-0.409	0.240	0.110	0.436	0.000	0.819	0.179	0.000	0.416	0.000	1.193	0.213	0.000
	Strength (°C)	0.019	0.600	1.553	2.900	0.600	0.301	0.002	-7.546	2.213	0.002	0.294	0.000	-12.253	2.831	0.000
	Depth (m)	0.123	0.153	0.040	0.027	0.153	0.751	0.000	-0.101	0.011	0.000	0.688	0.000	-0.128	0.013	0.000
	Magnitude (°C)	0.176	0.093	2.814	1.571	0.093	0.631	0.000	-5.827	0.857	0.000	0.546	0.000	-7.935	1.090	0.000
	Surface Temperature	0.474	0.002	-2.042	0.556	0.002	0.412	0.000	3.050	0.701	0.000	0.310	0.000	3.758	0.845	0.000
	Impact (°C)	0.051	0.382	1.907	2.115	0.382	0.367	0.000	-6.714	1.697	0.000	0.321	0.000	-9.730	2.135	0.000
1600h	Frequency (%)	0.195	0.066	-0.944	0.479	0.066	0.495	0.000	-11.366	2.170	0.000	0.326	0.000	2.099	0.450	0.000
	Strength (°C)	0.000	0.955	-0.048	0.833	0.955	0.370	0.000	-4.940	1.217	0.000	0.035	0.205	-2.072	1.612	0.205
	Depth (m)	0.538	0.001	0.028	0.006	0.001	0.660	0.000	-0.050	0.007	0.000	0.460	0.000	-0.054	0.009	0.000
	Magnitude (°C)	0.502	0.001	1.646	0.409	0.001	0.625	0.000	-2.798	0.410	0.000	0.407	0.000	-3.175	0.571	0.000
	Surface Temperature	0.490	0.001	-1.324	0.337	0.001	0.474	0.000	1.593	0.317	0.000	0.345	0.000	2.069	0.425	0.000
	Impact (°C)	0.280	0.024	4.876	1.953	0.024	0.392	0.000	1.425	0.335	0.000	0.247	0.000	-11.714	3.050	0.000
Daily	Frequency (%)	0.195	0.076	-0.626	0.329	0.076	0.472	0.000	1.198	0.244	0.000	0.433	0.000	1.696	0.293	0.000
	Strength (°C)	0.000	0.982	0.033	1.470	0.982	0.354	0.001	-6.685	1.740	0.001	0.118	0.018	-5.751	2.342	0.018
	Depth (m)	0.475	0.002	1.924	0.506	0.002	0.637	0.000	-4.036	0.586	0.000	0.350	0.000	-3.994	0.811	0.000
	Magnitude (°C)	0.476	0.002	0.042	0.011	0.002	0.694	0.000	-0.070	0.009	0.000	0.560	0.000	-0.081	0.011	0.000
	Surface Temperature	0.440	0.004	-1.836	0.535	0.004	0.430	0.000	2.571	0.570	0.000	0.373	0.000	3.426	0.669	0.000
	Impact (°C)	0.102	0.211	3.060	2.341	0.211	0.450	0.000	-8.834	1.879	0.000	0.383	0.000	-12.125	2.319	0.000

Note: Linear regressions are assumed to be significant at $p = 0.05$ (see Table 2). Violations of the assumptions of the linear model have not been checked.

3.2.3 Monthly data

Whilst all trends of the inversion parameters are assumed to be significant on an annual basis, when evaluated on a monthly basis, the results varied. In Table 2, the generalized tendencies (increase/decrease) for inversion characteristics, averaged between 1956 and 2003, have been summarized by month. An overall increase in a parameter's value is indicated by an upward facing arrow, while an overall decrease is signified by a downward arrow. The hyphen indicates that the regression analysis for the variable could not be assumed significant at 95%. Detailed statistical results are presented in Appendix B.

Table 2 – General tendencies for inversion characteristics by month (1956-2003)

	Daily					0400h					1600h				
	Frequency	Depth	Strength	Magnitude	Surface	Frequency	Depth	Strength	Magnitude	Surface	Frequency	Depth	Magnitude	Strength	Surface
January	-	↓	↓	↓	-	-	↓	-	↓	-	-	↓	↓	↓	-
February	↑	↓	↓	↓	-	-	↓	↓	↓	-	-	↓	↓	↓	↑
March	-	↓	↓	↓	↑	-	↓	-	-	-	-	-	-	-	-
April	↑	↓	-	-	-	↑	↓	-	-	-	-	-	-	-	-
May	↑	↓	-	↓	-	↑	↓	-	↓	-	-	-	-	-	-
June	↑	↓	-	↓	-	↑	↓	-	↓	-	-	-	-	-	-
July	↑	↓	-	↓	↑	↑	↓	-	↓	↑	-	-	-	-	-
August	↑	↓	-	↓	↑	↑	↓	-	↓	↑	-	-	-	-	-
September	↑	↓	-	↓	-	↑	↓	-	↓	-	↑	-	-	-	-
October	↑	↓	-	↓	-	↑	↓	-	↓	-	↑	-	-	-	-
November	↑	↓	↓	↓	-	↑	↓	↓	↓	-	↑	↓	↓	↓	-
December	↑	↓	↓	↓	-	↑	↓	↓	↓	-	↑	↓	↓	↓	↑
Annual	↑	↓	↓	↓	↑	↑	↓	↓	↓	↑	↑	↓	↓	↓	↑

Inversion frequency, depth, and magnitude are the parameters with the clearest and most consistent monthly trends. Increases in inversion frequency, which were assumed to be significant, occurred for 9 months of the year at 0400h, for the 4 winter months at 1600h, and for 10 months for the daily averages. Assumed significant decreases in the depth and magnitude of nocturnal inversions occurred throughout the year with the exception of the magnitude values for March and April. Assumed significant decreases for 1600h inversion depth and magnitude occurred exclusively in the winter. Inversion strength declined in all winter months except January at 0400h and in all the winter months at 1600h. Assumed statistically significant increases for the surface temperature during an inversion increase were limited to July and August in the 0400h soundings and December and February for the 1600h launches.

3.3 Intra-annual inversion characteristics

Inversion characteristics vary throughout the year in response to solar heating and radiatiative cooling (Wahl et al., 1987). Since synoptic activity in the Arctic leads to an altered definition of season (Serreze et al., 1992), summer in the southern Yukon was defined as the four months from May to August, and winter as the four months from November to February (Purves, 2006). Shoulder seasons were identified as the remainder of the year. The average values for each of the chosen parameters are compiled by month in Table 3. Results for individual years are presented in Appendix A.

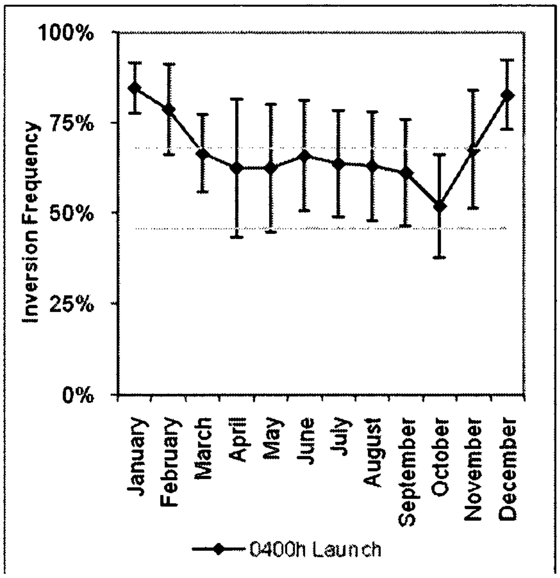
Table 3 – Summary of results for inversion characteristics by month (1956-2003)

Summary (1956-2003)		January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Inversion Frequency $_{0400h}$	XBAR	84.8%	78.8%	66.5%	62.5%	62.5%	65.9%	63.7%	63.0%	61.2%	52.0%	67.7%	82.7%	67.6%
	SD	7.0%	12.5%	10.8%	19.3%	17.8%	15.4%	14.7%	15.1%	14.9%	14.4%	16.5%	9.5%	14.0%
Inversion Frequency $_{1600h}$	XBAR	78.9%	50.1%	7.8%	0.9%	0.5%	1.9%	1.5%	0.8%	2.2%	11.9%	49.2%	79.5%	23.8%
	SD	9.3%	12.9%	6.8%	2.2%	1.6%	4.8%	5.1%	1.7%	4.6%	9.5%	17.8%	10.7%	7.3%
Inversion Depth $_{0400h}$ (m)	XBAR	596	472	302	237	252	262	267	275	262	273	391	534	344
	SD	212	174	93	62	94	67	81	77	77	107	177	230	121
Inversion Depth $_{1600h}$ (m)	XBAR	591	503	397	291	111	173	162	207	224	299	431	527	326
	SD	213	225	223	314	64	112	88	145	179	173	201	222	180
Inversion Strength $_{0400h}$ (°C)	XBAR	9.1	6.3	4.7	2.9	3.0	3.1	2.8	3.2	2.9	2.4	4.3	7.2	4.3
	SD	3.6	2.1	1.4	0.9	0.7	0.8	0.7	0.8	0.9	0.9	1.4	2.7	1.4
Inversion Strength $_{1600h}$ (°C)	XBAR	7.7	4.8	2.6	2.8	0.8	1.9	1.6	1.2	1.3	1.6	3.7	6.2	3.0
	SD	2.9	1.9	1.9	3.2	0.6	2.5	1.2	0.8	1.7	1.0	1.5	2.6	1.8
Inversion Magnitude $_{0400h}$ (°C)	XBAR	12.6	9.5	6.8	4.9	5.0	5.3	5.0	5.3	4.8	4.5	7.1	10.6	6.8
	SD	4.8	3.1	1.8	1.2	1.0	1.2	1.2	1.3	1.2	1.6	2.6	4.2	2.1
Inversion Magnitude $_{1600h}$ (°C)	XBAR	11.3	8.2	5.2	4.5	2.4	4.3	2.2	2.3	2.3	3.7	6.8	9.7	5.2
	SD	4.2	3.5	3.4	5.2	4.2	5.6	1.3	1.9	2.0	2.3	2.8	4.1	3.4
Near-Surface Air Temperature on Inversion Days $_{0400h}$ (°C)	XBAR	-19.6	-15.0	-12.2	-4.5	0.7	5.5	8.2	6.8	2.6	-2.9	-10.7	-16.3	-4.8
	SD	7.5	5.2	3.9	2.3	1.4	1.4	1.4	1.5	1.5	2.2	4.4	5.9	3.2
Near-Surface Air Temperature on Inversion Days $_{1600h}$ (°C)	XBAR	-18.0	-12.0	-6.7	-0.9	7.6	12.4	14.5	10.1	7.2	-0.2	-9.3	-15.1	-0.9
	SD	7.0	4.9	6.5	5.9	6.6	6.7	3.3	3.7	6.9	4.2	4.4	5.5	5.5
1971-2000 Temperature Normal (°C)	XBAR	-17.7	-13.7	-6.6	0.9	6.9	11.8	14.1	12.5	7.1	0.6	-9.4	-14.9	-0.7
Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	XBAR	10.7	7.5	4.3	3.1	3.1	3.4	3.3	3.3	2.9	2.6	5.1	8.4	4.8
	SD	4.3	2.8	1.7	1.3	1.0	1.3	1.0	1.1	1.0	1.2	2.1	3.9	1.9
Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	XBAR	9.1	4.1	0.4	0.0	0.0	0.1	0.0	0.0	0.0	0.4	3.2	7.7	2.1
	SD	3.9	2.0	0.4	0.1	0.0	0.2	0.1	0.0	0.1	0.5	1.6	3.6	1.0
Impact of Inversion on Surface Temperature (°C)	XBAR	9.9	5.8	2.3	1.6	1.6	1.7	1.7	1.7	1.5	1.5	4.1	7.8	3.4
	SD	4.0	2.3	1.0	0.7	0.5	0.6	0.5	0.6	0.5	0.8	1.7	3.9	1.4

3.3.1 Inversion Frequency

Nocturnal low-level inversion events were present in all of the months, ranging from a minimum frequency of 52% (October) to a maximum of 85% (January) (Table 3 and Figure 5). Afternoon soundings showed much greater monthly variability, occurring less than 2.2% of the time between April and September, but almost 80% of the time in December and January. On a seasonal basis, inversions occurred 64% of the time in afternoon in the winter, and 79% of the nights. Afternoon inversions were very rare in the summer (<2.2%), while night-time inversions remained common (64%). The shoulder seasons exhibited intermediate values, except for the fall (September – October), which had the lowest night-time frequency (57%). Elevated intra-annual variability for inversion frequency occurred between February and November for 0400h (± 15%) and in October through February, inclusively, at 1600h (± 12%). Between 1956-1973 and 1974-2003, the most obvious seasonal change occurs between March and October when inversion frequency 25-50% increases from 21% to 28% of the time. (Figure 6)

The reduced inversion frequency during the summer months is associated with reduced stability due to turbulent mixing in the boundary layer and strong advection due to the passage of fronts (Abdul-Wahab, 2003). The absence of similar conditions (as the result of low solar radiation inputs) during the winter months allows inversions to persist undisturbed for a longer period of time, which on a monthly-scale translates into increased inversion frequency.



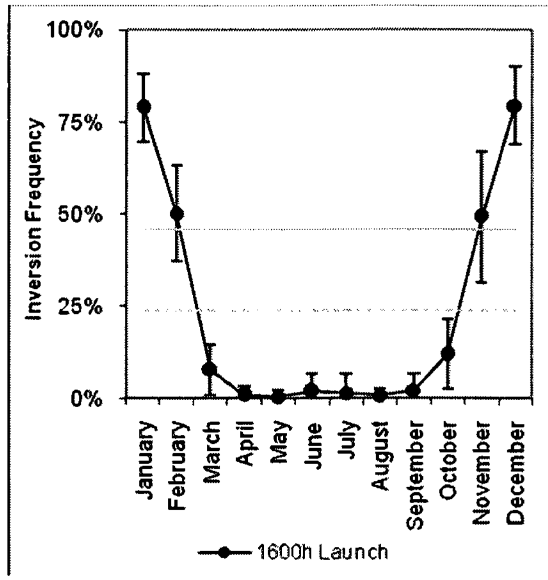
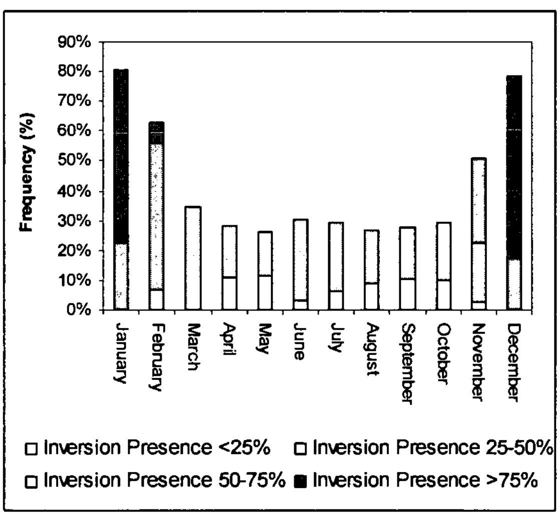


Figure 5.1 – Monthly variations in average inversion frequency (1956-2003) relative to average annual frequency (solid grey line) calculated at the daily-scale (0400h + 1600h) and for the 0400h launch (dashed grey line)

Figure 5.2 – Monthly variations in average inversion frequency (1956-2003) relative to average annual frequency (solid grey line) calculated at the daily-scale (0400h + 1600h) and for the 1600h launch (dashed grey line)



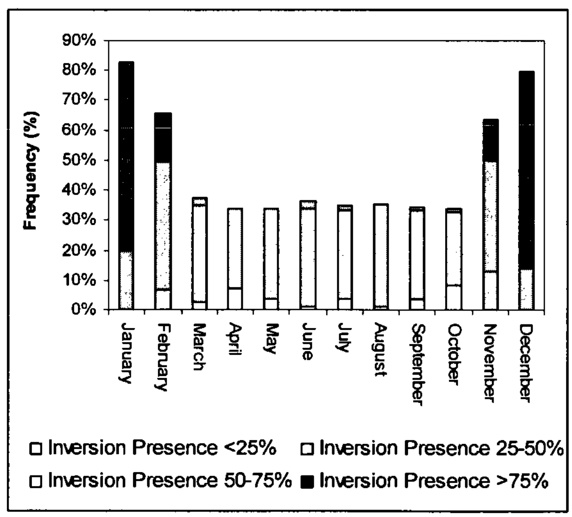


Figure 6.1 – Distribution of average inversion frequency (0400h + 1600h) by month for 1956-1973

Figure 6.2 – Distribution of average inversion frequency (0400h + 1600h) by month for 1974-2003

3.3.2 Inversion Depth

Surface based inversions are deepest during the winter months and shallowest throughout the summer and into the shoulder seasons, especially in the afternoon launch (Table 3 and Figure 7). Average inversion depths are almost the same for the 0400h and 1600h launches during the winter: maximum average values are greatest in January, reaching almost 600 m in each case. Reduced depths, all of which are less than 300 m, occur in the summer. Minima occur in April for night time launches and in May for 1600h, when the average value dips to 111 m (based on only 7 events in the 47 year record). Surprisingly, the average depths in March – April are greater at 1600h than 0400h, whereas the fall averages are very similar. Standard deviations in excess of 100 metres – or almost one third the annual average depth values – occur in the winter and both the spring and fall shoulder months at 0400h, and in all months except May and July at 1600h. Other than in December, when the 0400h standard deviation is at its maximum (± 230 m), afternoon variability is consistently greater at 1600h. Changes in the distribution of intra-annual depth values occur between 1956-1973 and 1974-2003. Winter depth values in excess of 750 m decrease from 24% to 6%, and disappear entirely in November after 1974. Depth values 250-500 m between March and October decrease by almost half. On the contrary, inversion depths of less than 250 m become four times more prevalent and occur throughout the year during 1974-2003. (Figure 8)

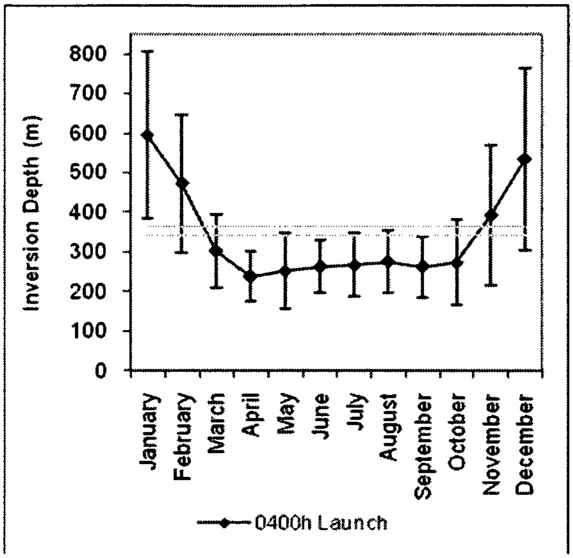


Figure 7.1 – Monthly variations in average inversion depth (1956-2003) relative to average annual depth (solid grey line) calculated at the daily-scale (0400h + 1600h) and for the 0400h launch (dashed grey line)

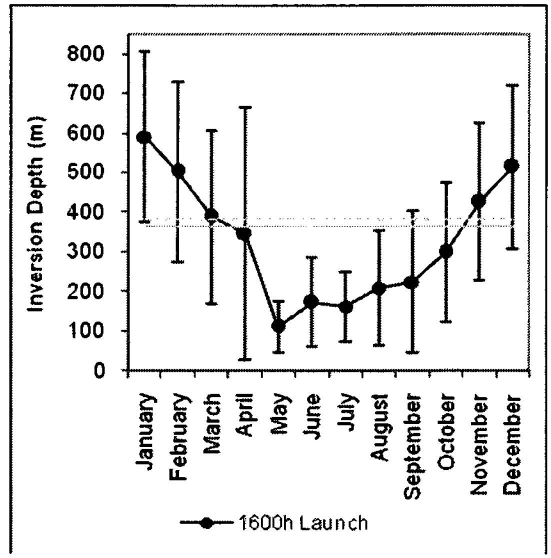
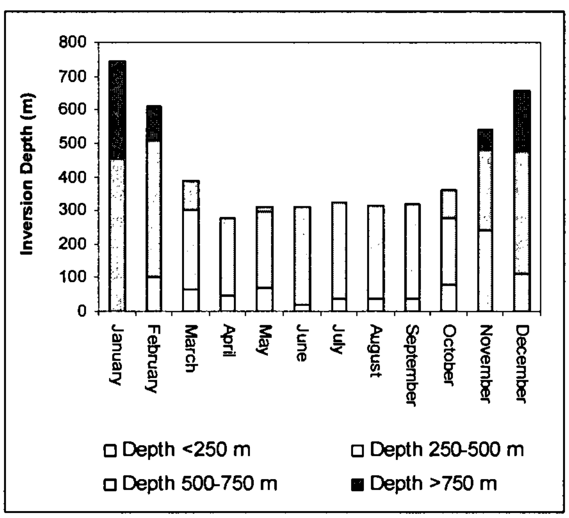


Figure 7.2 – Monthly variations in average inversion depth (1956-2003) relative to average annual depth (solid grey line) calculated at the daily-scale (0400h + 1600h) and for the 1600h launch (dashed grey line)



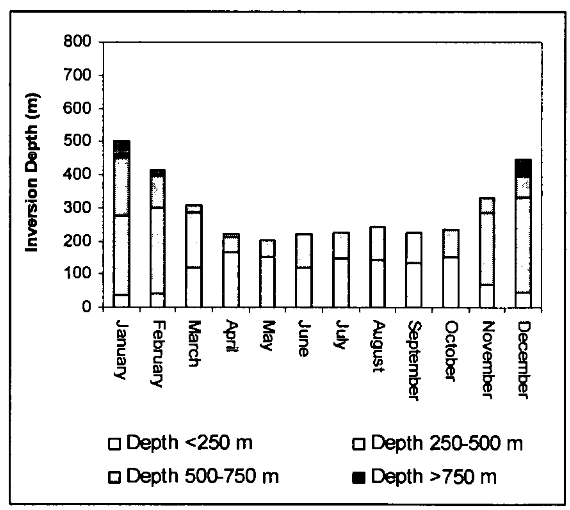


Figure 8.1 – Distribution of average inversion depth (0400h + 1600h) by month for 1956-1973

Figure 8.2 – Distribution of average inversion depth (0400h + 1600h) by month for 1974-2003

3.3.3 Inversion Strength

Inversion strength refers to the temperature difference across the inversion layer and is indicative of the thermal stability of the atmosphere (Abdul-Wahab, 2003).

The monthly variability in inversion strength at Whitehorse shows trends similar to those for inversion depth, except that the 0400h launch had higher average inversion strength in every month. As with depth, maximum strength values for both launch times were greatest in January, at 7.7°C during the day and 9.1°C at night. Averages fell to below 3°C for the 0400h launch between April and October, with the latter having the lowest value. For the 1600h sounding, the May value was lowest, although values were <2°C until October, inclusively. Overall, surface based inversions were strongest during the winter and weakest during the summer and fall, with spring showing intermediate values. (Table 3 and Figure 9) Maximum variability was identified during the winter and shoulder seasons at 0400h and 1600h and in June at 1600h. The distribution of average inversion depth by month between 1956-1973 and 1974-2003 shows less change than for the depth and frequency parameters. Between March and November, inversion strength <5°C is consistently dominant between the two periods. The greatest change occurs during December-February, when the presence of strong surface-based inversions, on the order of 7.5-10°C and >10°C, decreases from 48% for 1956-1973 to 30% for 1974-2003. (Figure 10)

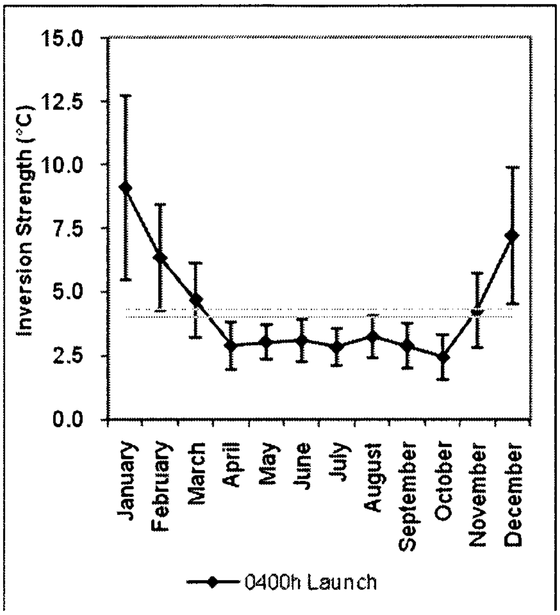


Figure 9.1 – Monthly variations in average inversion strength (1956-2003) relative to average annual strength (solid grey line) calculated at the daily-scale (0400h + 1600h) and for the 0400h launch (dashed grey line)

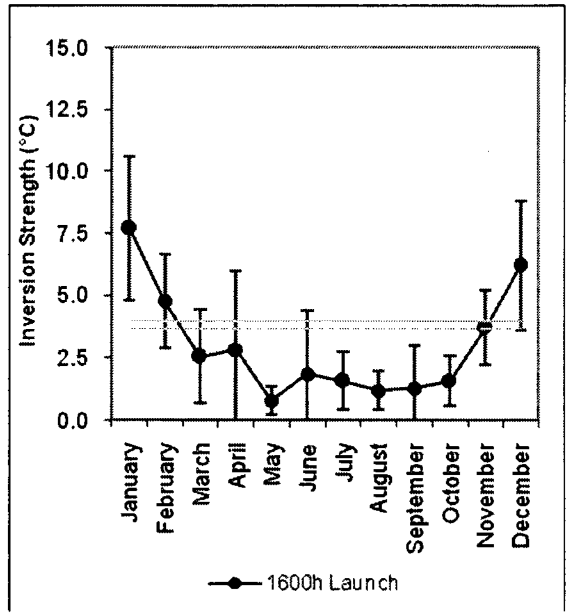


Figure 9.2 – Monthly variations in average inversion strength (1956-2003) relative to average annual strength (solid grey line) calculated at the daily-scale (0400h + 1600h) and for the 1600h launch (dashed grey line)

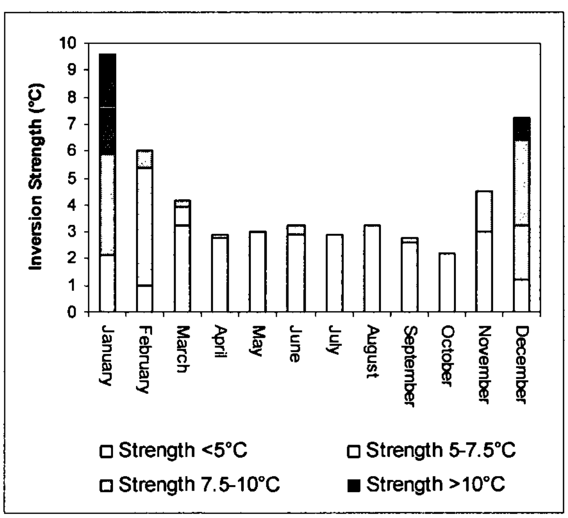


Figure 10.1 – Distribution of average inversion strength (0400h + 1600h) by month for 1956-1973

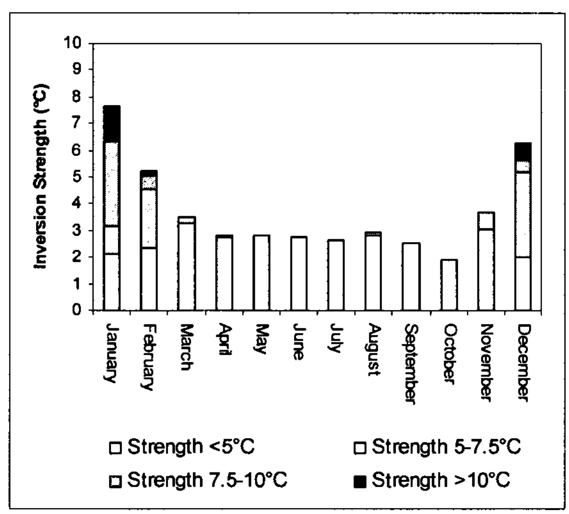


Figure 10.2 – Distribution of average inversion strength (0400h + 1600h) by month for 1974-2003

3.3.4 Inversion magnitude and inversion impact on near surface temperatures

Monthly trends for inversion magnitude followed those of the other calculated parameters quite closely (Table 3 and Figure 11). Inversion magnitude was greatest in both morning and afternoon soundings during the winter, reaching maxima in January that exceeded 11°C. The lowest values were for the fall for the 0400h sounding, with summer a close second. The reverse was true for the 1600h sounding which was lowest in the summer. Maximum variability was identified during the winter at 0400h, but varied greatly throughout the year at 1600h, reaching its maxima in (5.6°C) in June. Between 1956-1973 and 1974-2003, the distribution of inversion magnitude >5°C decreases by for all months. From 1974 to 2003, inversion magnitude <5°C is almost doubled and appears throughout the year, including January. (Figure 12)

The difference between inversion magnitude (Figure 11) and inversion strength (Figure 9) represents the potential influence of the normal (negative) lapse rate projected through the top of the inversion (Figure 1). This varied on a seasonal basis from maxima of 3.2-3.4°C in winter (for the two sounding times) to fall minima of 1.5-2.0°C.

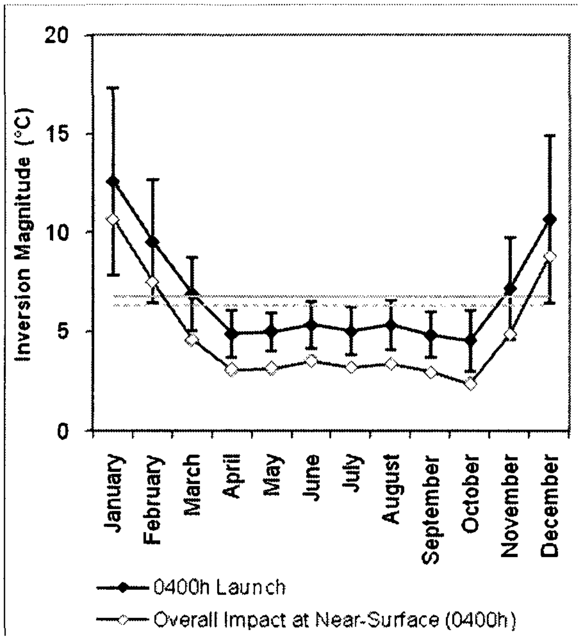


Figure 11.1 – Monthly variations in average inversion magnitude (1956-2003) relative to average annual magnitude (solid grey line) calculated at the daily-scale (0400h + 1600h) and for the 0400h launch (dashed grey line)

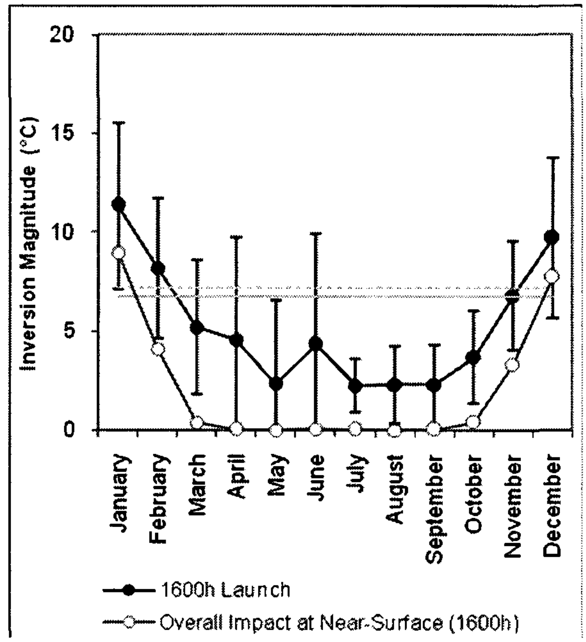


Figure 11.2 – Monthly variations in average inversion magnitude (1956-2003) relative to average annual magnitude (solid grey line) calculated at the daily-scale (0400h + 1600h) and for the 1600h launch (dashed grey line)

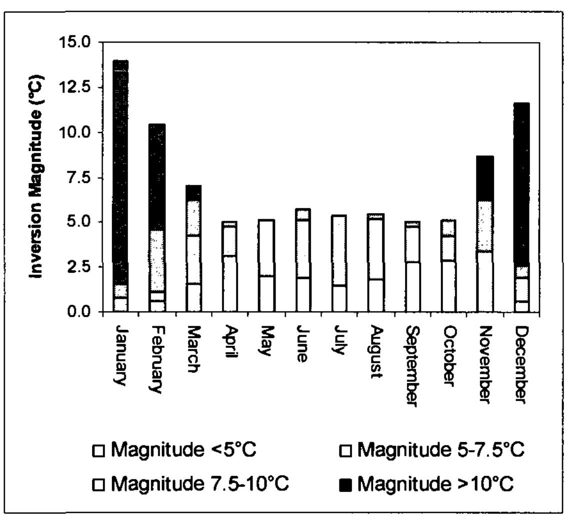


Figure 12.1 – Distribution of average inversion magnitude (0400h + 1600h) by month for 1956-1973

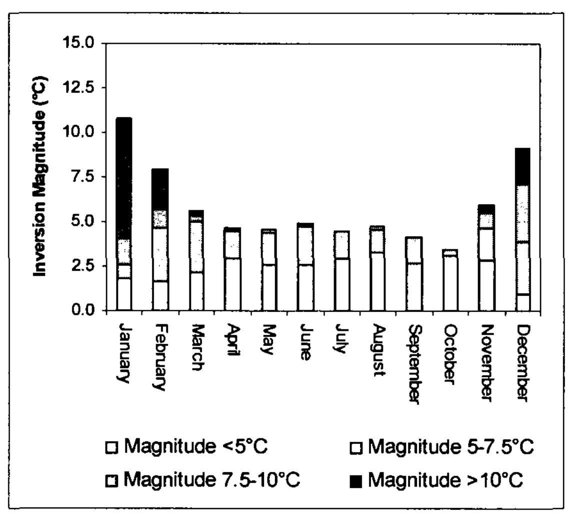
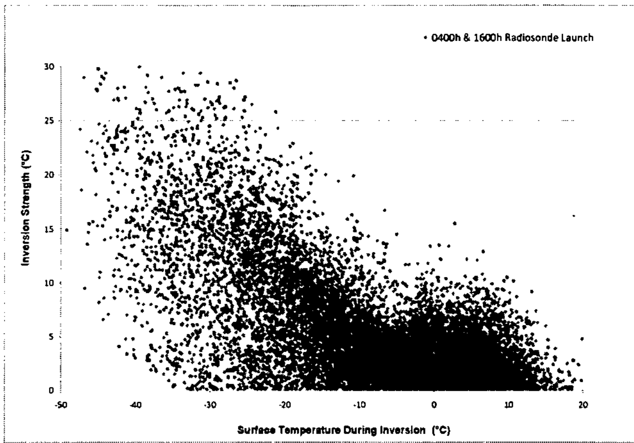


Figure 12.2 – Distribution of average inversion magnitude (0400h + 1600h) by month for 1974-2003

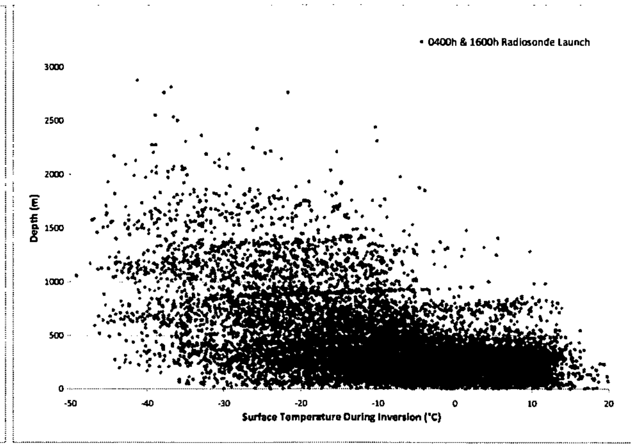
3.4 Relationships among inversion parameters

Scatterplots were drawn for the daily (0400h + 1600h) and the 0400h and 1600h (Appendix C) launch times in order to illustrate the relationships between the parameters of the inversion profile (strength, depth, magnitude, surface temperature) (Figure 13). Moderate positive correlations were revealed among inversion depth, strength, and magnitude, and each of these variables was found to be inversely related to surface temperature during an inversion. All of the plotted relationships were calculated to be statistically significant at the 95% confidence level, based on the assumption that the residuals are identically and independently distributed. Calculated r^2 values range from 0.17 (surface temperature vs. inversion magnitude) to 0.65 (inversion magnitude vs. depth). Full correlation analyses are provided in Appendix C.

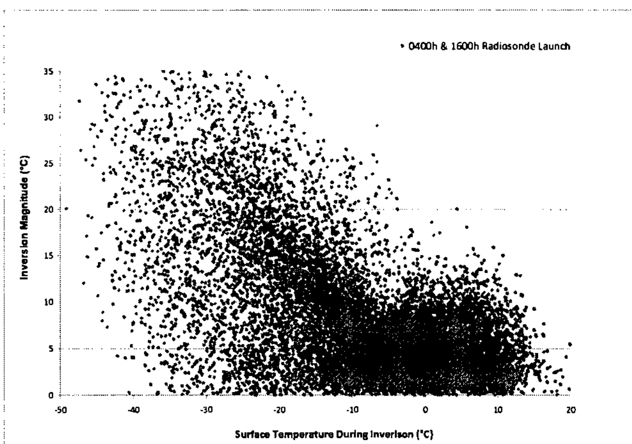
The scatterplots show that individual inversions vary widely in terms of the parameters studied. For example, at a near-surface temperature of -30°C, inversion strength has varied from close to zero to 30°C, magnitude from zero to 35°C, and depth up to nearly 3000m. On average, however, surface-based inversions at Whitehorse are likely to be deepest and strongest during the winter months, when increased magnitude and frequency values have the greatest potential to impact cold surface temperatures. Intense polar night inversions are known to develop occasionally, but overall, strong inversions remain much less frequent than weaker ones (see histograms in section 3.2). Generally, very strong surface-based inversions are limited to when warming westerly winds develop aloft soon after a cold spell is established at the surface (Wahl et al., 1987).



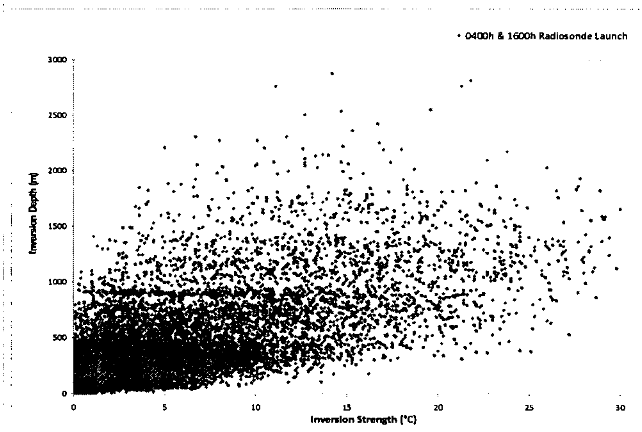
13.1 – Correlation of inversion strength and near-surface temperatures during inversions



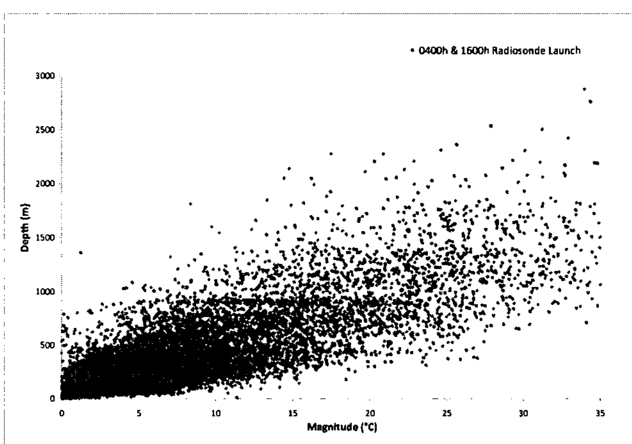
13.2 – Correlation of inversion depth and near-surface temperatures during inversions



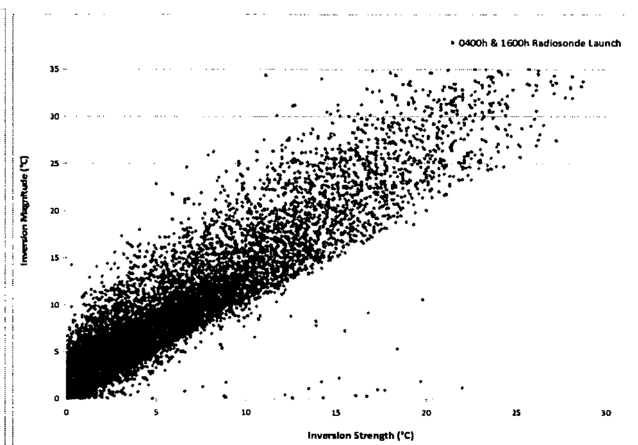
13.3 – Correlation of inversion magnitude and near-surface temperatures during inversions



13.4 – Correlation of inversion depth and inversion strength



13.5 – Correlation of inversion depth and inversion magnitude



13.6 – Correlation of inversion magnitude and inversion strength

Figure 13: Correlations of inversion parameters within the atmospheric profile (all records)

3.5 Twice-daily radiosonde data relative to the remainder of the day

An important question relates to the representativeness of the twice-daily radiosonde data at the synoptic scale. Hourly screen height air temperatures measured for one year along an elevation transect from 1010 to 1290 m asl, about 13 km south of Whitehorse Airport, suggest that the twice-daily values should be adequate to represent conditions. The 0400h and 1600h values of inversion frequency did not represent the diurnal maxima and minima (Figure 14) which occur at approximately 0700h and 1800h. However, the average of the two frequencies was 24.7%, which was almost identical to the average for all hours in the day (25.4%). Similarly, the strength of the inversions, when present in the valley, averaged 3.1°C (over 280 m) for all hours and when calculated for 0400h and 1600h. This raises confidence that averages of the radiosonde result and their trends are reflective of the overall conditions.

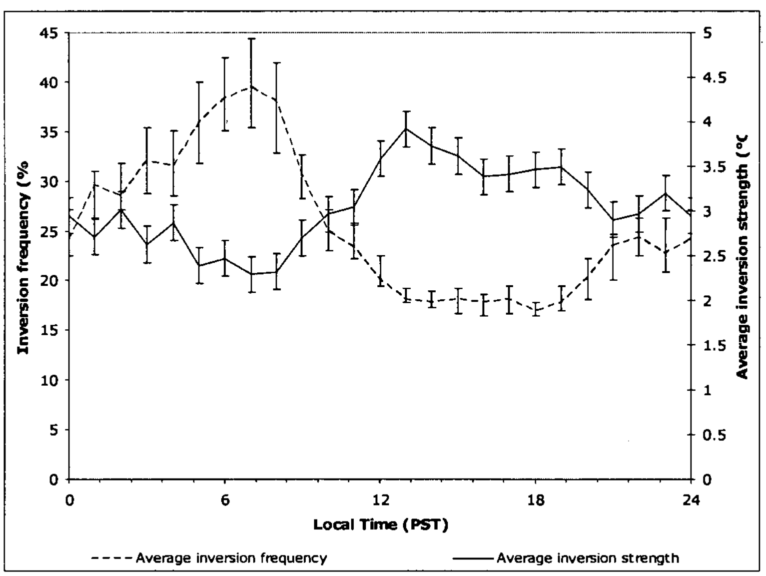


Figure 14 – 24-hour altitudinal screen height temperature data recorded at Mount Sima (07/2004 – 06/2005)

Note: Error bars on strength reflect the range of values associated with errors of ±0.2°C at each of the air temperature monitoring stations; those on frequency represent the range of possible results for the presence of inversion given the same measurement error.

3.6 Low-level inversions in an area of discontinuous permafrost

Whitehorse's location within a zone of discontinuous permafrost, where the independent average surface temperature is already quite close to zero (-0.7°C; National Climate Archive, Environment Canada 2007) means that even a small change in temperature could have a widespread impact on permafrost distribution (Lewkowicz and Smith, 2004). While climate change is known to be playing a critical role in the presence and extent of permafrost in the Yukon Plateaus, the frequency and characteristics of surface-based air temperature inversions appear to be equally important to permafrost maintenance. Although the definitive shape of the upper-air profile (<1250m) at Whitehorse suggests that permafrost is likely in the valley bottom (where temperatures are depressed by the inversion) and unlikely up-slope (where temperatures are increased at the locations that correspond with inversion tops), before any definitive conclusions can be made, linkages between the patterns of change (1956-2003) identified in the current work and ground surface temperatures are still required. By confirming the relationships that exist between near-surface temperatures and ground-surface temperatures collected along altitudinal transects in areas close to Whitehorse (Coal Ridge and Mount Sima) and the upper-air radiosonde data for Whitehorse Airport this will be possible.

4 CONCLUSIONS

The following conclusions can be reached from this study of the radiosonde data at Whitehorse:

[1] At the daily scale, surface-based inversions occurred 46% of the time, with average inversion frequencies ranging from 52% in October to above 80% in December and January for the 0400 radiosonde sounding, and from less than 2.2% between April and September to almost 80% in December and January at 1600h. Of the total number of inversions identified, approximately three quarters (74%) originated during the night and were radiative in nature. Nocturnal low-level inversion events occurred 68% of the time and throughout the year. They were deeper, more frequent, and

stronger in winter. Daytime inversions, in contrast, were primarily a winter phenomena, limited to 24% of the readings between October and March.

[2] Inversion magnitude, strength, and depth have all decreased between 1956 and 2003, in both the morning (0400h) and afternoon (1600h) radiosonde soundings. As a daily average, decreases were in the order of -4.5°C for magnitude, -2°C for inversion strength, and -335 m for inversion depth. In all cases, the amount of change was greater in the afternoon reading than in the morning. In contrast, inversion frequency increased by approximately +12% between 1956 and 2003.

[3] Recent climatic warming (>1974) and cooling periods (1942-1973) are reflected in changes to the characteristics of surface-based inversions over Whitehorse. There appears to be a prominent link between inversion parameters and the dramatic North Pacific climate shift, known to have taken place in 1976 and to have coincided with a change in the phase of the Pacific Decadal Oscillation (PDO). Between 1956-1973 and 1974-2003 shorter, weaker, lower magnitude inversions appear as progressively more frequent. The 0400h radiosonde launch indicated average decreases in inversion depth (-128 m), strength (-0.4°C), and magnitude (-1.5°C), accompanied by average increases in surface temperatures on inversion days (+1.3°C) and inversion frequency (+8%). Trends are magnified in the 1600h data for all parameters except frequency: depth, strength, and magnitude decreased respectively by -173 m, -0.5°C, and -1.8°C, respectively, while surface temperatures and inversion frequency increased by +1.5°C and +3%.

[4] The overall impact of regular radiative low-level inversions over Whitehorse, Yukon Territory is estimated to result in an average temperature reduction of -3.4°C near the ground surface. Given that the current air temperature in Whitehorse is -0.7°C and that this is barely low enough for permafrost, it is clear that temperature inversions have been contributing to the maintenance of a permafrost environment in the region of the Yukon Plateaus. If the trends described in this paper continue, further

reductions in inversion impact may lead to loss of permafrost in lower parts of the Yukon Plateaus. The reverse could also be assumed true: during a period of cooling, trends in inversion characteristics opposite to those presented in this paper could result in permafrost aggradation.

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5 THESIS SUMMARY

This research explored long-term seasonal characteristics and the inter-annual trends of surface-based temperature inversions above Whitehorse, Yukon Territory over a period of 47 years (1956 -2003). Through the identification and extraction of seasonal and inter-annual trends within the data set and the definition of the association between inversions presence and near surface temperatures the following extended conclusions were drawn:

[1] At the daily scale, surface-based inversions occurred 46% of the time, with average inversion frequencies ranging from 52% in October to above 80% in December and January for the 0400 radiosonde sounding, and from less than 2.2% between April and September to almost 80% in December and January at 1600h. Of the total number of inversions identified, approximately three quarters (74%) originated during the night and were likely radiative in nature. Nocturnal low-level inversion events occurred 68% of the time and throughout the year. They were deeper, more frequent, and stronger in winter. Daytime inversions, in contrast, were primarily a winter phenomena, limited to 24% of the readings between October and March.

[2] Inversion magnitude, strength, and depth have all decreased between 1956 and 2003, in both the morning (0400h) and afternoon (1600h) radiosonde soundings. As a daily average, decreases were in the order of -4.5°C for magnitude, -2°C for inversion strength, and -335 m for inversion depth. In all cases, the amount of change was greater in the afternoon reading than in the morning. In contrast, inversion frequency increased by approximately +12% between 1956 and 2003.

[3] Recent climatic warming (>1974) and cooling periods (1942-1973) are reflected in changes to the characteristics of surface-based inversions over Whitehorse. There appears to be a prominent link between inversion parameters and the dramatic North Pacific climate shift, known to have taken place

in 1976 and to have coincided with a change in the phase of the Pacific Decadal Oscillation (PDO). Between 1956-1973 and 1974-2003 shorter, weaker, lower magnitude inversions appear as progressively more frequent. The 0400h radiosonde launch indicated average decreases in inversion depth (-128 m), strength (-0.4°C), and magnitude (-1.5°C), accompanied by average increases in surface temperatures on inversion days (+1.3°C) and inversion frequency (+8%). Trends are magnified in the 1600h data for all parameters except frequency: depth, strength, and magnitude decreased respectively by -173 m, -0.5°C, and -1.8°C, respectively, while surface temperatures and inversion frequency increased by +1.5°C and +3%.

[4] The overall impact of regular radiative low-level inversions over Whitehorse, Yukon Territory is estimated to result in an average temperature reduction of -3.4°C near the ground surface. Given that the current air temperature in Whitehorse is -0.7°C and that this is barely low enough for permafrost, it is clear that temperature inversions have been contributing to the maintenance of a permafrost environment in the region of the Yukon Plateaus. If the trends described in this paper continue, further reductions in inversion impact may lead to loss of permafrost in lower parts of the Yukon Plateaus. The reverse could also be assumed true: during a period of cooling, trends in inversion characteristics opposite to those presented in this paper could result in permafrost aggradation.

[5] The overall trends of the inversion parameters are cannot be assumed as statistically significant at the monthly scale. While decreases in the magnitude and depth of nocturnal radiation inversions are found throughout the year (with the exception of the magnitude values calculated for March and April), corresponding decreases for 1600h inversion magnitude, depth and strength, and 0400h inversion strength are exclusive to the winter months (November – February). Likewise, increased 0400h frequencies are assumed to be significant between April and December, but are restricted to September – December during the afternoon inversion event.

[6] Positive, moderately correlated relationships (assumed to be statistically significant at the 95% confidence level, although violation of the linear model were not checked) occur between inversion strength, depth and magnitude parameters. The same parameters are inversely related to surface temperature. Accordingly, it is understood that surface-based inversions at Whitehorse are deepest and strongest during the winter months, when increased magnitude and frequency values have the greatest potential to impact cold surface temperatures.

[7] Hourly screen height air temperatures measured (07/2004 – 06/2005) on a slope in the Yukon River valley, 13 km south of Whitehorse airport surface, were almost perfectly representative of the balloon launch averages (for surface based inversion frequency and strength) calculated for Whitehorse Airport between 1956 and 2003. Even though the plotted transect results suggest that diurnal maximums/minimums are occurring at 0700h and 1800h, the average frequency (24.7%) for the 0400h and 1600h surface based readings was almost perfectly representative of the balloon launch data for the same times (25.1%). This raises confidence that trends in radiosonde results are reflective of the changes in overall inversion characteristics.

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APPENDIX A: Summary data – inversion characteristics by month by year (1956-2003)

1956	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	31	29	31	29	31	30	31	31	30	31	29	30	
Number of Soundings $_{1600h}$	31	29	31	30	31	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	77.4%	53.3%	40.6%	31.0%	9.7%	6.7%	19.4%	9.7%	33.3%	48.4%	34.5%	70.0%	36.2%
Inversion Frequency $_{1600h}$	67.7%	44.8%	16.1%	3.3%	0.0%	3.3%	0.0%	0.0%	3.3%	25.8%	36.7%	64.5%	22.1%
Average Inversion Depth $_{0400h}$ (m)	649	554	397	300	723	337	365	481	427	416	383	570	467
Average Inversion Depth $_{1600h}$ (m)	664	464	42	-	-	342	-	-	144	90	698	590	379
Average Inversion Strength $_{0400h}$ (°C)	9.8	6.5	6.4	4.2	4.0	1.4	2.3	3.0	4.3	3.4	4.3	8.4	4.8
Average Inversion Strength $_{1600h}$ (°C)	8.5	4.9	2.0	-	-	9.5	-	-	6.3	0.4	5.6	7.5	5.6
Average Magnitude $_{0400h}$ (°C)	4.3	4.4	6.2	6.7	5.3	3.0	4.3	4.4	6.1	3.5	4.5	3.7	4.7
Average Magnitude $_{1600h}$ (°C)	6.3	5.1	2.0	-	-	12.0	-	-	7.2	0.8	7.7	4.1	5.7
Average Surface Temperature $_{0400h}$ (°C)	-23.7	-19.5	-14.0	-5.8	2.4	7.5	11.0	8.0	2.6	-8.8	-6.8	-23.7	-5.9
Average Surface Temperature $_{1600h}$ (°C)	-22.8	-15.9	-25.6	-	-	1.3	-	-	-3.1	-7.5	-9.6	-20.4	-12.9
Average Monthly Temperature $_{ALL}$ (°C)	-22.2	-17.6	-9.7	0.9	7.4	10.5	14.9	13.2	6.8	-2.8	-3.2	-21.3	-1.9
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	3.3	2.3	2.5	2.1	0.5	0.2	0.8	0.4	2.0	1.7	1.6	2.6	1.7
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	4.2	2.3	0.3	0.0	0.0	0.4	0.0	0.0	0.2	0.2	2.8	2.6	1.1
Overall Impact of Inversion on Surface Temperature (°C)	3.8	2.3	1.4	1.0	0.3	0.3	0.4	0.2	1.1	1.0	2.2	2.6	1.4

1957	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	31	28	31	30	31	30	31	31	30	31	29	31	
Number of Soundings $_{1600h}$	31	28	31	30	31	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	83.9%	82.1%	67.7%	86.7%	77.4%	60.0%	67.7%	61.3%	73.3%	58.1%	82.8%	87.1%	74.0%
Inversion Frequency $_{1600h}$	77.4%	60.7%	6.5%	0.0%	0.0%	0.0%	3.2%	3.2%	0.0%	19.4%	60.0%	83.9%	26.2%
Average Inversion Depth $_{0400h}$ (m)	692	495	368	314	331	351	318	322	307	512	304	476	399
Average Inversion Depth $_{1600h}$ (m)	665	530	156	-	-	-	130	142	-	631	378	566	400
Average Inversion Strength $_{0400h}$ (°C)	14.3	8.3	6.7	2.6	2.1	4.3	2.8	3.7	3.0	5.8	4.6	5.6	5.3
Average Inversion Strength $_{1600h}$ (°C)	12.1	5.8	2.3	-	-	-	1	2	-	1.7	3.4	5.9	4.2
Average Magnitude $_{0400h}$ (°C)	18.0	11.7	9.4	5.0	4.4	7.0	5.3	6.6	5.1	9.2	7.7	9.7	8.2
Average Magnitude $_{1600h}$ (°C)	16.1	9.1	3.1	-	-	-	1	3	-	5.8	6.1	10.6	6.8
Average Surface Temperature $_{0400h}$ (°C)	-21.9	-17.3	-11.2	-5.2	3.2	7.1	7.8	9.5	6.2	-3.4	-5.6	-15.0	-3.8
Average Surface Temperature $_{1600h}$ (°C)	-20.3	-13.2	-3.4	-	-	-	12	9	-	3.2	-3.6	-15.7	-4.0
Average Monthly Temperature $_{ALL}$ (°C)	-20.0	-13.9	-4.8	0.3	7.8	13.8	13.5	15.4	11.2	1.4	-3.0	-15.2	0.5
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	15.1	9.6	6.4	4.3	3.4	4.2	3.6	4.0	3.7	5.3	6.3	8.4	6.2
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	12.5	5.5	0.2	0.0	0.0	0.0	0.0	0.1	0.0	1.1	3.7	8.9	2.7
Impact of Inversion on Surface Temperature (°C)	13.8	7.6	3.3	2.2	1.7	2.1	1.8	2.1	1.9	3.2	5.0	8.6	4.4

1958	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	31	28	31	30	31	30	31	31	30	31	30	31	
Number of Soundings $_{1600h}$	31	28	31	30	31	30	31	31	30	30	30	31	
Inversion Frequency $_{0400h}$	90.3%	75.0%	74.2%	76.7%	48.4%	73.3%	74.2%	38.7%	56.7%	51.6%	46.7%	87.1%	66.1%
Inversion Frequency $_{1600h}$	64.5%	60.7%	3.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	13.3%	40.0%	87.1%	22.4%
Average Inversion Depth $_{0400h}$ (m)	486	625	279	293	326	290	288	244	338	308	399	470	362
Average Inversion Depth $_{1600h}$ (m)	516	484	132	-	-	-	-	-	-	280	369	529	385
Average Inversion Strength $_{0400h}$ (°C)	7.5	8.3	4.3	3.6	3.3	4.0	2.5	2.5	3.2	3.2	5.9	8.2	4.7
Average Inversion Strength $_{1600h}$ (°C)	7.2	4.6	1.5	-	-	-	-	-	-	2.3	5.0	7.1	4.6
Average Magnitude $_{0400h}$ (°C)	10.7	12.1	6.1	5.9	5.2	6.3	4.8	4.4	5.7	5.5	8.8	10.9	7.2
Average Magnitude $_{1600h}$ (°C)	11.4	7.5	1.4	-	-	-	-	-	-	3.3	7.7	10.4	6.9
Average Surface Temperature $_{0400h}$ (°C)	-12.9	-19.0	-10.2	-1.6	3.7	8.6	11.0	5.4	1.2	-6.5	-11.5	-15.4	-3.9
Average Surface Temperature $_{1600h}$ (°C)	-13.1	-14.7	1.7	-	-	-	-	-	-	-2.9	-13.3	-15.0	-9.5
Average Monthly Temperature $_{ALL}$ (°C)	-11.4	-16.6	-6.4	3.5	8.6	16.0	16.7	11.7	6.0	-1.7	-8.0	-15.5	0.2
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	9.6	9.1	4.5	4.5	2.5	4.6	3.6	1.7	3.2	2.8	4.1	9.5	5.0
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	7.3	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	3.1	9.0	2.0
Impact of Inversion on Surface Temperature (°C)	8.5	6.8	2.3	2.2	1.3	2.3	1.8	0.9	1.6	1.6	3.6	9.3	3.5

1959	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	31	28	31	30	31	30	31	31	30	31	30	31	
Number of Soundings $_{1600h}$	31	28	31	30	31	29	30	31	30	31	30	31	
Inversion Frequency $_{0400h}$	93.5%	82.1%	67.7%	53.3%	25.8%	70.0%	38.7%	38.7%	43.3%	35.5%	66.7%	61.3%	56.4%
Inversion Frequency $_{1600h}$	87.1%	46.4%	16.1%	3.3%	0.0%	3.4%	0.0%	0.0%	0.0%	6.5%	33.3%	54.8%	20.9%
Average Inversion Depth $_{0400h}$ (m)	680	328	287	219	236	317	311	308	259	235	402	322	325
Average Inversion Depth $_{1600h}$ (m)	622	390	360	370	-	369	-	-	-	115	365	294	361
Average Inversion Strength $_{0400h}$ (°C)	10.3	6.0	5.8	2.3	2.0	2.6	1.9	1.7	2.0	2.4	4.0	4.2	3.8
Average Inversion Strength $_{1600h}$ (°C)	8.1	4.4	4.1	4.6	-	0.8	-	-	-	1.7	4.4	3.3	3.9
Average Magnitude $_{0400h}$ (°C)	13.7	8.2	8.2	3.7	3.7	5.7	4.1	4.2	4.0	3.9	6.7	6.5	6.0
Average Magnitude $_{1600h}$ (°C)	10.7	6.7	7.3	4.9	-	3.6	-	-	-	3.3	6.3	5.6	8.1
Average Surface Temperature $_{0400h}$ (°C)	-27.7	-13.6	-15.1	-5.1	0.5	7.3	7.2	6.1	3.5	-5.9	-11.2	-10.2	-5.3
Average Surface Temperature $_{1600h}$ (°C)	-27.1	-11.6	-13.5	-5.6	-	15.6	-	-	-	1.1	-10.1	-9.3	-7.6
Average Monthly Temperature $_{ALL}$ (°C)	-27.9	-10.6	-10.6	-0.7	6.7	13.7	13.3	10.8	7.3	-1.3	-7.1	-7.6	-1.2
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	12.8	6.8	5.5	2.0	1.0	4.0	1.6	1.6	1.7	1.4	4.4	4.0	3.9
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	9.3	3.1	1.2	0.2	0.0	0.1	0.0	0.0	0.0	0.2	2.1	3.1	1.6
Impact of Inversion on Surface Temperature (°C)	11.1	4.9	3.3	1.1	0.5	2.1	0.8	0.8	0.9	0.8	3.3	3.5	2.8

1960	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	31	29	31	30	31	30	31	31	30	31	30	31	
Number of Soundings $_{1600h}$	31	29	31	30	31	30	30	31	30	31	29	31	
Inversion Frequency $_{0400h}$	83.9%	79.3%	67.7%	86.7%	77.4%	60.0%	67.7%	61.3%	73.3%	58.1%	80.0%	87.1%	73.5%
Inversion Frequency $_{1600h}$	77.4%	58.6%	6.5%	0.0%	6.5%	0.0%	0.0%	0.0%	0.0%	19.4%	62.1%	83.9%	26.2%
Average Inversion Depth $_{0400h}$ (m)	526	450	280	280	257	241	212	310	230	246	357	361	312
Average Inversion Depth $_{1600h}$ (m)	634	281	740	-	192	-	-	-	-	317	350	265	397
Average Inversion Strength $_{0400h}$ (°C)	10.2	7.5	4.5	2.6	3.6	1.6	1.6	4.1	2.2	1.9	4.7	5.5	4.2
Average Inversion Strength $_{1600h}$ (°C)	8.9	3.0	4.7	-	0	-	-	-	-	1.3	3.3	3.7	3.6
Average Magnitude $_{0400h}$ (°C)	13.2	10.6	6.2	5.1	5.8	3.2	2.7	6.7	3.9	4.0	7.1	7.9	6.4
Average Magnitude $_{1600h}$ (°C)	12.6	4.5	7.0	-	0	-	-	-	-	2.6	6.0	5.3	5.4
Average Surface Temperature $_{0400h}$ (°C)	-17.4	-13.3	-14.9	-2.3	1.8	5.8	9.0	5.4	2.0	-1.2	-11.0	-11.5	-4.0
Average Surface Temperature $_{1600h}$ (°C)	-15.1	-7.8	-9.8	-	7	-	-	-	-	0.0	-8.2	-8.2	-6.0
Average Monthly Temperature $_{ALL}$ (°C)	-16.1	-10.4	-9.7	2.1	7.9	11.3	13.3	12.1	7.7	1.3	-8.0	-8.3	0.3
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	11.1	8.4	4.2	4.4	4.5	1.9	1.8	4.1	2.9	2.3	5.7	6.9	4.9
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	9.7	2.7	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	3.7	4.4	1.8
Impact of Inversion on Surface Temperature (°C)	10.4	5.5	2.3	2.2	2.3	1.0	0.9	2.1	1.4	1.4	4.7	5.6	3.3

1961	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	31	28	31	30	31	30	31	31	30	31	29	31	364
Number of Soundings $_{1600h}$	31	28	31	30	31	30	30	31	30	31	30	31	364
Inversion Frequency $_{0400h}$	87.1%	53.6%	67.7%	50.0%	45.2%	50.0%	51.6%	48.4%	66.7%	45.2%	69.0%	87.1%	60.1%
Inversion Frequency $_{1600h}$	87.1%	32.1%	9.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.5%	40.0%	83.9%	21.6%
Average Inversion Depth $_{0400h}$ (m)	697	690	582	287	286	336	330	304	357	332	618	1082	492
Average Inversion Depth $_{1600h}$ (m)	631	542	738	-	-	-	-	-	-	326	717	1108	677
Average Inversion Strength $_{0400h}$ (°C)	8.2	5.4	7.3	2.4	3.2	2.0	2.7	2.9	2.6	2.4	5.9	12.4	4.8
Average Inversion Strength $_{1600h}$ (°C)	6.6	4.3	3.4	-	-	-	-	-	-	1.8	5.3	11.9	5.5
Average Magnitude $_{0400h}$ (°C)	14.0	11.0	12.2	5.0	5.3	4.3	5.0	5.4	5.0	5.3	11.0	20.1	8.6
Average Magnitude $_{1600h}$ (°C)	11.9	8.7	10.8	-	-	-	-	-	-	4.6	11.0	18.0	10.8
Average Surface Temperature $_{0400h}$ (°C)	-13.3	-13.4	-15.3	-4.9	-0.9	5.7	9.5	6.3	2.9	-4.6	-15.3	-24.3	-5.6
Average Surface Temperature $_{1600h}$ (°C)	-12.0	-12.8	-14.1	-	-	-	-	-	-	-0.8	-13.7	-24.4	-13.0
Average Monthly Temperature $_{ALL}$ (°C)	-13.3	-12.0	-8.3	-0.4	6.5	11.1	15.1	12.3	6.8	-1.4	-13.0	-24.9	-1.8
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	12.2	5.9	8.3	2.5	2.4	2.2	2.6	2.6	3.3	2.4	7.6	17.5	5.8
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	10.3	2.8	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	4.4	15.1	2.8
Impact of Inversion on Surface Temperature (°C)	11.3	4.4	4.7	1.2	1.2	1.1	1.3	1.3	1.7	1.3	6.0	16.3	4.3

1962	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	30	28	31	30	31	30	31	31	30	31	30	31	
Number of Soundings $_{1600h}$	31	28	31	30	31	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	76.7%	92.9%	64.5%	60.0%	54.8%	66.7%	77.4%	54.8%	63.3%	58.1%	70.0%	74.2%	67.8%
Inversion Frequency $_{1600h}$	80.6%	60.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	26.7%	77.4%	20.5%
Average Inversion Depth $_{0400h}$ (m)	677	757	382	260	277	299	347	297	364	202	343	786	416
Average Inversion Depth $_{1600h}$ (m)	805	889	-	-	-	-	-	-	-	-	498	682	718
Average Inversion Strength $_{0400h}$ (°C)	8.5	9.5	5.7	2.4	2.5	2.5	3.2	3.1	2.0	1.1	2.1	6.4	4.1
Average Inversion Strength $_{1600h}$ (°C)	7.4	7.0	-	-	-	-	-	-	-	-	3.0	5.9	5.8
Average Magnitude $_{0400h}$ (°C)	12.7	15.6	8.2	4.5	4.7	5.0	5.7	5.4	4.5	2.5	6.2	12.8	7.3
Average Magnitude $_{1600h}$ (°C)	12.5	13.7	-	-	-	-	-	-	-	-	8.6	11.6	11.6
Average Surface Temperature $_{0400h}$ (°C)	-19.6	-16.4	-17.1	-5.0	0.3	4.7	8.1	8.0	2.3	0.6	-5.7	-13.4	-4.4
Average Surface Temperature $_{1600h}$ (°C)	-15.8	-13.3	-	-	-	-	-	-	-	-	-8.0	-13.6	-12.7
Average Monthly Temperature $_{ALL}$ (°C)	-16.8	-13.6	-10.5	0.5	5.9	10.8	14.5	13.3	6.5	2.8	-5.9	-13.8	-0.5
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	9.7	14.5	5.3	2.7	2.6	3.4	4.4	3.0	2.8	1.5	4.4	9.5	5.3
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	10.0	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	9.0	2.5
Impact of Inversion on Surface Temperature (°C)	9.9	11.4	2.6	1.4	1.3	1.7	2.2	1.5	1.4	0.7	3.3	9.2	3.9

1963	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	31	28	31	30	31	30	31	31	30	31	30	31	
Number of Soundings $_{1600h}$	31	28	31	30	31	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	83.9%	67.9%	58.1%	76.7%	71.0%	43.3%	51.6%	71.0%	43.3%	41.9%	70.0%	77.4%	63.0%
Inversion Frequency $_{1600h}$	87.1%	50.0%	3.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.2%	33.3%	74.2%	20.9%
Average Inversion Depth $_{0400h}$ (m)	908	665	416	264	290	300	310	446	273	383	570	685	459
Average Inversion Depth $_{1600h}$ (m)	786	686	439	-	-	-	-	-	-	171	574	567	537
Average Inversion Strength $_{0400h}$ (°C)	10.8	6.1	4.5	2.9	4.3	2.2	3.5	4.7	2.4	1.8	6.2	7.7	4.8
Average Inversion Strength $_{1600h}$ (°C)	10.6	6.1	1.3	-	-	-	-	-	-	0.9	8.0	7.5	5.7
Average Magnitude $_{0400h}$ (°C)	17.1	11.9	7.0	4.7	6.2	4.0	5.7	8.1	4.7	5.0	10.7	12.0	8.1
Average Magnitude $_{1600h}$ (°C)	15.2	10.8	5.8	-	-	-	-	-	-	4.0	11.9	12.5	10.0
Average Surface Temperature $_{0400h}$ (°C)	-15.9	-10.2	-12.2	-5.1	0.5	3.7	7.9	7.7	6.1	-1.3	-16.0	-12.4	-3.9
Average Surface Temperature $_{1600h}$ (°C)	-14.1	-8.8	-9.9	-	-	-	-	-	-	0.4	-20.1	-13.2	-11.0
Average Monthly Temperature $_{ALL}$ (°C)	-14.2	-8.9	-9.7	-1.6	7.3	9.8	14.2	14.6	9.4	2.9	-16.5	-10.3	-0.3
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	14.4	8.1	4.1	3.6	4.4	1.7	2.9	5.7	2.1	2.1	7.5	9.3	5.5
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	13.3	5.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	4.0	9.3	2.7
Impact of Inversion on Surface Temperature (°C)	13.8	6.7	2.1	1.8	2.2	0.9	1.5	2.9	1.0	1.1	5.7	9.3	4.1

1964	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	31	29	31	30	31	30	31	31	30	31	30	31	
Number of Soundings $_{1600h}$	31	29	31	30	31	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	83.9%	75.9%	74.2%	46.7%	35.5%	53.3%	48.4%	58.1%	63.3%	54.8%	70.0%	54.8%	59.9%
Inversion Frequency $_{1600h}$	74.2%	27.6%	12.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.2%	33.3%	58.1%	17.4%
Average Inversion Depth $_{0400h}$ (m)	639	391	396	386	302	290	264	276	324	260	309	1019	405
Average Inversion Depth $_{1600h}$ (m)	640	482	620	-	-	-	-	-	-	458	431	842	579
Average Inversion Strength $_{0400h}$ (°C)	7.4	3.9	6.2	3.2	3.3	3.1	3.7	3.1	4.0	2.2	2.6	9.5	4.4
Average Inversion Strength $_{1600h}$ (°C)	6.6	5.8	3.2	-	-	-	-	-	-	1.6	2.1	6.8	4.3
Average Magnitude $_{0400h}$ (°C)	10.2	7.1	9.1	6.4	5.3	6.0	6.0	5.0	6.5	5.0	5.1	14.7	7.2
Average Magnitude $_{1600h}$ (°C)	12.3	9.8	7.2	-	-	-	-	-	-	4.3	5.3	11.9	8.5
Average Surface Temperature $_{0400h}$ (°C)	-14.7	-9.9	-20.1	-7.2	0.4	5.9	5.2	4.7	1.4	-1.2	-11.8	-28.8	-6.3
Average Surface Temperature $_{1600h}$ (°C)	-15.4	-12.1	-10.9	-	-	-	-	-	-	0.9	-9.5	-25.9	-12.2
Average Monthly Temperature $_{ALL}$ (°C)	-15.9	-6.5	-14.7	-0.8	4.4	13.3	12.9	11.6	7.4	2.0	-9.3	-24.6	-1.7
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	8.5	5.4	6.8	3.0	1.9	3.2	2.9	2.9	4.1	2.7	3.6	8.0	4.4
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	9.1	2.7	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.8	6.9	1.8
Impact of Inversion on Surface Temperature (°C)	8.8	4.0	3.8	1.5	0.9	1.6	1.5	1.4	2.1	1.4	2.7	7.5	3.1

1965	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	31	28	31	30	31	30	31	31	30	31	30	31	
Number of Soundings $_{1600h}$	31	28	31	30	31	30	31	31	30	30	30	31	
Inversion Frequency $_{0400h}$	80.6%	75.0%	58.1%	46.7%	58.1%	53.3%	67.7%	61.3%	66.7%	35.5%	66.7%	74.2%	62.0%
Inversion Frequency $_{1600h}$	67.7%	50.0%	6.5%	0.0%	0.0%	0.0%	0.0%	0.0%	3.3%	6.7%	60.0%	67.7%	21.8%
Average Inversion Depth $_{0400h}$ (m)	784	681	389	257	326	311	333	330	390	213	872	546	453
Average Inversion Depth $_{1600h}$ (m)	749	794	556	-	-	-	-	-	477	700	936	559	681
Average Inversion Strength $_{0400h}$ (°C)	8.1	7.9	2.5	2.8	2.5	2.2	4.5	4.9	4.2	2.5	7.7	5.1	4.6
Average Inversion Strength $_{1600h}$ (°C)	7.9	5.7	0.7	-	-	-	-	-	1.9	1.0	6.8	4.7	4.1
Average Magnitude $_{0400h}$ (°C)	13.3	13.0	4.6	4.7	5.3	4.8	7.1	7.0	6.8	4.5	15.1	9.8	8.0
Average Magnitude $_{1600h}$ (°C)	12.2	10.7	5.3	-	-	-	-	-	4.1	7.5	13.1	9.4	8.9
Average Surface Temperature $_{0400h}$ (°C)	-20.5	-20.3	-7.3	-5.0	-0.3	4.0	6.9	5.8	3.3	-3.3	-13.7	-14.9	-5.4
Average Surface Temperature $_{1600h}$ (°C)	-23.4	-18.8	-2.3	-	-		-	-	13.2	-4.1	-12.2	-15.5	-9.0
Average Monthly Temperature $_{ALL}$ (°C)	-19.3	-19.1	-2.7	0.5	5.2	10.0	14.5	13.0	9.2	0.6	-12.3	-15.1	-1.3
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	10.7	9.7	2.7	2.2	3.1	2.5	4.8	4.3	4.6	1.6	10.1	7.3	5.3
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	8.3	5.4	0.3	0.0	0.0	0.0	0.0	0.0	0.1	0.5	7.9	6.4	2.4
Impact of Inversion on Surface Temperature (°C)	9.5	7.5	1.5	1.1	1.5	1.3	2.4	2.1	2.3	1.1	9.0	6.8	3.8

1966	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	31	28	31	30	31	29	31	29	30	31	30	31	
Number of Soundings $_{1600h}$	31	28	31	30	31	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	90.3%	71.4%	54.8%	50.0%	35.5%	79.3%	71.0%	44.8%	46.7%	35.5%	46.7%	87.1%	59.4%
Inversion Frequency $_{1600h}$	93.5%	53.6%	9.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.2%	33.3%	83.9%	23.1%
Average Inversion Depth $_{0400h}$ (m)	1055	542	419	298	236	301	343	310	294	349	598	720	455
Average Inversion Depth $_{1600h}$ (m)	1066	627	813	-	-	-	-	-	-	436	687	724	726
Average Inversion Strength $_{0400h}$ (°C)	18.0	8.0	4.6	2.7	2.4	3.3	3.0	3.0	2.7	2.2	6.6	7.2	5.3
Average Inversion Strength $_{1600h}$ (°C)	14.3	4.9	3.4	-	-	-	-	-	-	2.5	5.5	6.8	6.2
Average Magnitude $_{0400h}$ (°C)	23.2	12.3	8.3	4.5	4.5	6.3	5.9	5.0	5.0	4.9	10.3	11.3	8.5
Average Magnitude $_{1600h}$ (°C)	22.0	9.6	10.6	-	-		-	-		5.6	11.3	11.6	11.8
Average Surface Temperature $_{0400h}$ (°C)	-32.3	-16.4	-14.1	-5.9	-1.7	4.6	8.5	4.9	1.9	-5.9	-17.8	-16.5	-7.6
Average Surface Temperature $_{1600h}$ (°C)	-30.1	-12.4	-15.7	-	-		-	-		-11.2	-14.3	-16.1	-16.6
Average Monthly Temperature $_{ALL}$ (°C)	-31.7	-11.8	-9.0	-0.2	5.4	12.4	15.2	11.4	7.7	-1.5	-14.1	-17.0	-2.8
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	21.0	8.8	4.6	2.3	1.6	5.0	4.2	2.3	2.4	1.7	4.8	9.8	5.7
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	20.6	5.2	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	3.8	9.7	3.4
Impact of Inversion on Surface Temperature (°C)	20.8	7.0	2.8	1.1	0.8	2.5	2.1	1.1	1.2	1.0	4.3	9.8	4.5

1967	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	31	28	31	30	31	30	31	31	30	31	30	31	
Number of Soundings $_{1600h}$	31	28	31	30	31	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	80.6%	75.0%	67.7%	66.7%	67.7%	63.3%	61.3%	54.8%	50.0%	54.8%	56.7%	77.4%	64.7%
Inversion Frequency $_{1600h}$	67.7%	50.0%	6.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.2%	40.0%	83.9%	20.9%
Average Inversion Depth $_{0400h}$ (m)	761	478	384	327	296	327	289	302	217	212	626	743	413
Average Inversion Depth $_{1600h}$ (m)	659	590	379	-	-	-	-	-	-	132	700	669	522
Average Inversion Strength $_{0400h}$ (°C)	8.5	4.9	6.0	5.3	4.1	3.6	2.6	2.8	2.6	1.6	3.5	8.6	4.5
Average Inversion Strength $_{1600h}$ (°C)	7.1	4.3	1.6	-	-	-	-	-	-	0.2	4.2	7.5	4.1
Average Magnitude $_{0400h}$ (°C)	13.5	8.5	8.1	7.7	6.4	6.3	5.1	5.2	4.9	3.8	8.3	15.1	7.7
Average Magnitude $_{1600h}$ (°C)	11.8	9.0	5.0	-	-		-	-		0.9	10.2	12.7	8.3
Average Surface Temperature $_{0400h}$ (°C)	-21.4	-13.0	-18.5	-8.0	-0.3	6.5	6.3	8.1	2.5	-1.3	-9.5	-16.6	-5.4
Average Surface Temperature $_{1600h}$ (°C)	-20.2	-12.4	-1.3	-	-		-	-		3.7	-8.3	-16.3	-9.1
Average Monthly Temperature $_{ALL}$ (°C)	-20.1	-12.4	-13.0	-2.1	6.4	14.2	12.9	13.8	8.5	1.3	-6.7	-15.3	-1.0
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	10.9	6.4	5.5	5.1	4.3	4.0	3.1	2.9	2.4	2.1	4.7	11.7	5.3
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	8.0	4.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1	10.7	2.3
Impact of Inversion on Surface Temperature (°C)	9.4	5.4	2.9	2.6	2.2	2.0	1.6	1.4	1.2	1.1	4.4	11.2	3.8

1968	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	31	29	31	30	30	30	31	30	30	31	30	31	
Number of Soundings $_{1600h}$	31	29	31	30	31	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	74.2%	79.3%	61.3%	33.3%	63.3%	66.7%	51.6%	60.0%	30.0%	38.7%	80.0%	80.6%	59.9%
Inversion Frequency $_{1600h}$	67.7%	44.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.2%	53.3%	80.6%	20.8%
Average Inversion Depth $_{0400h}$ (m)	620	692	290	252	289	279	372	304	281	311	490	848	419
Average Inversion Depth $_{1600h}$ (m)	662	966	-	-	-	-	-	-	-	446	615	787	695
Average Inversion Strength $_{0400h}$ (°C)	8.3	8.3	2.8	1.7	3.4	3.2	3.4	3.7	1.1	2.2	4.2	12.4	4.6
Average Inversion Strength $_{1600h}$ (°C)	7.5	6.6	-	-	-	-	-	-	-	0.8	3.8	9.3	5.6
Average Magnitude $_{0400h}$ (°C)	13.1	13.8	5.3	3.4	6.3	5.5	6.4	6.4	3.0	5.4	8.4	18.4	8.0
Average Magnitude $_{1600h}$ (°C)	12.9	14.2	-	-	-	-	-	-	-	6.8	8.9	15.1	11.6
Average Surface Temperature $_{0400h}$ (°C)	-20.9	-14.8	-9.0	-5.5	1.1	3.7	7.8	5.4	2.6	-4.6	-10.7	-25.9	-5.9
Average Surface Temperature $_{1600h}$ (°C)	-19.8	-16.8	-	-	-	-	-	-	-	-5.6	-10.3	-23.2	-15.1
Average Monthly Temperature $_{ALL}$ (°C)	-20.1	-10.1	-3.4	0.1	7.7	11.7	14.7	12.6	6.4	-0.7	-8.4	-24.1	-1.1
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	9.7	11.0	3.3	1.1	4.0	3.7	3.3	3.8	0.9	2.1	6.7	14.8	5.4
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	8.7	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	4.7	12.2	2.7
Impact of Inversion on Surface Temperature (°C)	9.2	8.7	1.6	0.6	2.0	1.8	1.6	1.9	0.5	1.2	5.7	13.5	4.0

1969	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	31	28	31	30	30	30	31	31	29	31	30	31	
Number of Soundings $_{1600h}$	31	28	31	30	31	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	93.5%	92.9%	54.8%	56.7%	60.0%	86.7%	38.7%	61.3%	48.3%	67.7%	10.0%	100.0%	64.2%
Inversion Frequency $_{1600h}$	93.5%	53.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	22.6%	10.0%	100.0%	23.3%
Average Inversion Depth $_{0400h}$ (m)	994	697	348	207	281	334	492	279	273	528	223	626	440
Average Inversion Depth $_{1600h}$ (m)	1163	788	-	-	-	-	-	-	-	586	750	573	772
Average Inversion Strength $_{0400h}$ (°C)	12.8	6.4	6.1	2.3	3.6	5.7	2.8	3.7	1.9	4.9	4.2	6.0	5.0
Average Inversion Strength $_{1600h}$ (°C)	10.7	4.7	-	-	-	-	-	-	-	3.4	3.0	4.5	5.3
Average Magnitude $_{0400h}$ (°C)	17.8	11.4	9.1	4.2	5.5	8.7	6.7	5.6	3.7	9.4	10.9	11.5	8.7
Average Magnitude $_{1600h}$ (°C)	18.0	11.4	-	-	-	-	-	-	-	9.9	8.2	9.8	11.5
Average Surface Temperature $_{0400h}$ (°C)	-32.5	-17.0	-14.2	-3.8	1.5	6.9	6.0	3.1	3.0	-2.5	-14.2	-10.2	-6.2
Average Surface Temperature $_{1600h}$ (°C)	-30.6	-16.4	-	-	-	-	-	-	-	-1.6	-10.2	-9.7	-13.7
Average Monthly Temperature $_{ALL}$ (°C)	-32.7	-15.2	-5.9	2.0	7.8	15.6	12.6	8.7	7.2	2.5	-8.7	-8.4	-1.2
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	16.6	10.6	5.0	2.4	3.3	7.5	2.6	3.5	1.8	6.3	1.1	11.5	6.0
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	16.8	6.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.8	9.8	3.0
Impact of Inversion on Surface Temperature (°C)	16.7	8.4	2.5	1.2	1.6	3.8	1.3	1.7	0.9	4.3	1.0	10.6	4.5

1970	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	31	28	31	30	31	29	31	31	30	31	30	31	
Number of Soundings $_{1600h}$	31	28	31	30	31	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	87.1%	78.6%	61.3%	40.0%	54.8%	55.2%	64.5%	54.8%	56.7%	45.2%	53.3%	77.4%	60.7%
Inversion Frequency $_{1600h}$	67.7%	42.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	19.4%	43.3%	77.4%	20.9%
Average Inversion Depth $_{0400h}$ (m)	596	567	299	253	302	265	280	261	406	528	607	766	427
Average Inversion Depth $_{1600h}$ (m)	579	658	-	-	-	-	-	-	-	402	488	776	581
Average Inversion Strength $_{0400h}$ (°C)	5.7	6.6	3.0	2.1	2.8	2.9	2.9	3.1	1.8	3.8	4.7	7.5	3.9
Average Inversion Strength $_{1600h}$ (°C)	4.9	4.3	-	-	-	-	-	-	-	1.9	3.4	5.7	4.1
Average Magnitude $_{0400h}$ (°C)	10.1	11.4	5.7	4.4	5.6	4.9	5.2	4.8	4.6	8.3	8.7	13.6	7.3
Average Magnitude $_{1600h}$ (°C)	9.1	10.7	-	-	-	-	-	-	-	4.5	6.7	11.7	8.6
Average Surface Temperature $_{0400h}$ (°C)	-19.8	-9.5	-7.4	-4.6	0.7	3.2	6.2	4.7	1.2	-6.5	-11.5	-19.6	-5.3
Average Surface Temperature $_{1600h}$ (°C)	-17.5	-7.7	-	-	-	-	-	-	-	-3.4	-10.8	-17.6	-11.4
Average Monthly Temperature $_{ALL}$ (°C)	-18.3	-5.7	-2.1	1.0	6.7	10.6	12.5	11.1	6.0	-1.9	-10.1	-18.1	-0.7
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	8.8	8.9	3.5	1.8	3.1	2.7	3.4	2.6	2.6	3.7	4.7	10.5	4.7
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	6.2	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	2.9	9.1	2.0
Impact of Inversion on Surface Temperature (°C)	7.5	6.8	1.7	0.9	1.5	1.3	1.7	1.3	1.3	2.3	3.8	9.8	3.3

1971	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	31	28	31	30	31	29	31	31	30	31	30	31	
Number of Soundings $_{1600h}$	31	28	31	30	30	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	74.2%	67.9%	71.0%	40.0%	45.2%	69.0%	71.0%	64.5%	46.7%	25.8%	70.0%	71.0%	59.7%
Inversion Frequency $_{1600h}$	64.5%	35.7%	6.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	9.7%	40.0%	87.1%	20.3%
Average Inversion Depth $_{0400h}$ (m)	941	616	331	196	305	278	361	347	296	275	540	690	432
Average Inversion Depth $_{1600h}$ (m)	819	666	654	-	-	-	-	-	-	751	610	689	698
Average Inversion Strength $_{0400h}$ (°C)	12.6	6.4	4.7	2.0	2.5	4.8	2.9	2.9	3.3	2.5	4.8	7.8	4.8
Average Inversion Strength $_{1600h}$ (°C)	11.3	5.0	4.0	-	-	-	-	-	-	3.7	2.7	7.5	5.7
Average Magnitude $_{0400h}$ (°C)	17.6	11.5	7.3	3.9	4.9	7.4	5.8	5.6	5.4	4.3	9.6	13.0	8.0
Average Magnitude $_{1600h}$ (°C)	16.1	10.6	5.3	-	-	-	-	-		6.7	7.5	12.4	10.1
Average Surface Temperature $_{0400h}$ (°C)	-32.3	-14.1	-15.9	-6.3	-2.0	3.7	8.8	6.5	0.5	-3.6	-11.7	-21.7	-7.3
Average Surface Temperature $_{1600h}$ (°C)	-28.9	-12.7	-17.8	-	-		-	-		-5.3	-10.1	-21.1	-16.0
Average Monthly Temperature $_{ALL}$ (°C)	-28.7	-10.1	-10.3	0.0	5.1	11.8	15.8	12.9	6.3	-0.9	-10.8	-20.3	-2.4
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	13.0	7.8	5.2	1.6	2.2	5.1	4.1	3.6	2.5	1.1	6.7	9.2	5.2
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	10.4	3.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.8	3.0	10.8	2.4
Impact of Inversion on Surface Temperature (°C)	11.7	5.8	2.8	0.8	1.1	2.5	2.1	1.8	1.3	1.0	4.8	10.0	3.8

1972	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	31	29	31	30	31	30	31	31	30	31	30	31	
Number of Soundings $_{1600h}$	31	29	31	30	31	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	83.9%	96.6%	64.5%	63.3%	61.3%	70.0%	67.7%	48.4%	56.7%	54.8%	50.0%	83.9%	66.8%
Inversion Frequency $_{1600h}$	77.4%	58.6%	3.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	16.1%	46.7%	71.0%	22.8%
Average Inversion Depth $_{0400h}$ (m)	810	549	356	222	334	378	328	300	325	607	383	739	444
Average Inversion Depth $_{1600h}$ (m)	823	739	446	-	-	-	-	-	-	578	542	807	656
Average Inversion Strength $_{0400h}$ (°C)	12.3	6.4	6.3	4.3	3.7	2.9	4.7	3.1	2.0	3.2	3.0	8.2	5.0
Average Inversion Strength $_{1600h}$ (°C)	10.8	3.8	8.9	-	-	-	-	-	-	3.8	2.2	7.9	6.2
Average Magnitude $_{0400h}$ (°C)	17.9	9.5	8.7	6.9	7.1	5.6	7.1	5.4	4.4	8.1	6.1	14.2	8.4
Average Magnitude $_{1600h}$ (°C)	15.7	8.3	15.6	-	-	-	-	-		9.2	6.6	14.4	11.6
Average Surface Temperature $_{0400h}$ (°C)	-29.5	-23.3	-16.8	-12.1	-0.4	5.2	7.5	6.5	2.3	-3.0	-8.0	-17.8	-7.4
Average Surface Temperature $_{1600h}$ (°C)	-28.4	-18.4	-11.2	-	-		-	-	.	1.4	-6.2	-17.2	-13.3
Average Monthly Temperature $_{ALL}$ (°C)	-28.6	-21.8	-10.9	-5.1	6.0	11.1	13.8	12.5	5.2	-1.0	-6.7	-17.5	-3.6
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	15.0	9.2	5.6	4.3	4.3	3.9	4.8	2.6	2.5	4.5	3.0	11.9	6.0
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	12.1	4.8	0.5	0.0	0.0	0.0	0.0	0.0	0.0	1.5	3.1	10.2	2.7
Impact of Inversion on Surface Temperature (°C)	13.5	7.0	3.1	2.2	2.2	2.0	2.4	1.3	1.2	3.0	3.1	11.1	4.3

1973	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	31	28	31	30	30	30	30	31	30	31	30	31	
Number of Soundings $_{1600h}$	31	28	31	30	30	30	30	31	30	31	30	31	
Inversion Frequency $_{0400h}$	80.6%	85.7%	58.1%	36.7%	46.7%	53.3%	53.3%	61.3%	66.7%	58.1%	66.7%	90.3%	63.1%
Inversion Frequency $_{1600h}$	83.9%	42.9%	0.0%	3.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	46.7%	87.1%	22.0%
Average Inversion Depth $_{0400h}$ (m)	850	603	201	263	234	281	365	321	440	190	998	592	445
Average Inversion Depth $_{1600h}$ (m)	877	966	166	-	-	-	-	-	-	-	802	643	691
Average Inversion Strength $_{0400h}$ (°C)	11.6	8.1	3.3	1.8	2.3	3.1	2.2	3.1	4.4	1.1	7.6	8.2	4.7
Average Inversion Strength $_{1600h}$ (°C)	10.5	7.4	0.3	-	-	-	-	-	-	-	4.7	8.1	6.2
Average Magnitude $_{0400h}$ (°C)	16.7	12.9	5.4	3.9	4.0	5.2	5.7	5.2	8.2	3.3	12.9	12.7	8.0
Average Magnitude $_{1600h}$ (°C)	17.3	16.0	2.7	-	-		-	-			10.3	13.3	11.9
Average Surface Temperature $_{0400h}$ (°C)	-22.9	-19.3	-10.0	-4.5	-0.5	3.5	5.9	4.6	1.3	-1.9	-21.9	-17.4	-6.9
Average Surface Temperature $_{1600h}$ (°C)	-21.4	-13.8	1.9	-	-		-	-			-18.5	-16.7	-13.7
Average Monthly Temperature $_{ALL}$ (°C)	-23.2	-16.7	-5.4	1.2	6.0	10.7	13.2	10.1	7.0	0.1	-19.9	-17.4	-2.9
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	13.5	11.1	3.1	1.4	1.9	2.8	3.1	3.2	5.4	1.9	8.6	11.5	5.6
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	14.5	6.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8	11.6	3.1
Impact of Inversion on Surface Temperature (°C)	14.0	9.0	1.6	0.7	0.9	1.4	1.5	1.6	2.7	0.9	6.7	11.5	4.4

1974	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	31	28	31	30	31	30	31	31	30	30	30	31	
Number of Soundings $_{1600h}$	31	28	31	30	31	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	80.6%	82.1%	74.2%	43.3%	71.0%	60.0%	45.2%	58.1%	66.7%	16.7%	46.7%	67.7%	59.4%
Inversion Frequency $_{1600h}$	80.6%	53.6%	3.2%	0.0%	0.0%	0.0%	0.0%	3.2%	0.0%	0.0%	10.0%	67.7%	18.2%
Average Inversion Depth $_{0400h}$ (m)	870	554	341	243	259	278	272	417	315	211	487	432	390
Average Inversion Depth $_{1600h}$ (m)	801	635	470	-	-	-	-	461	-	-	358	342	511
Average Inversion Strength $_{0400h}$ (°C)	16.6	8.2	5.3	2.3	3.5	3.2	3.0	4.6	4.3	2.6	2.0	4.0	5.0
Average Inversion Strength $_{1600h}$ (°C)	12.5	8.0	0.6	-	-	-	-	2	-	-	3.4	3.1	5.0
Average Magnitude $_{0400h}$ (°C)	22.3	13.2	7.9	4.3	5.9	5.6	5.5	8.2	6.7	4.4	6.7	8.1	8.2
Average Magnitude $_{1600h}$ (°C)	18.5	13.1	3.5	-	-	-	-	7	-	-	6.0	7.3	9.3
Average Surface Temperature $_{0400h}$ (°C)	-30.3	-17.6	-16.3	-4.8	0.8	2.9	5.5	7.0	1.5	-4.0	-7.2	-10.9	-6.1
Average Surface Temperature $_{1600h}$ (°C)	-26.8	-17.7	-3.3	-	-	-	-	3	-	-	-5.7	-10.2	-10.2
Average Monthly Temperature $_{ALL}$ (°C)	-29.0	-14.2	-12.1	0.4	6.4	10.1	12.4	11.4	7.7	1.5	-4.5	-9.4	-1.6
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	18.0	10.8	5.8	1.8	4.2	3.3	2.5	4.8	4.4	0.7	3.1	5.5	5.4
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	14.9	7.0	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.6	4.9	2.3
Impact of Inversion on Surface Temperature (°C)	16.5	8.9	3.0	0.9	2.1	1.7	1.2	2.5	2.2	0.4	1.9	5.2	3.9

1975	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	31	28	31	30	31	30	31	31	30	31	30	31	
Number of Soundings $_{1600h}$	31	28	31	30	31	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	77.4%	67.9%	77.4%	33.3%	54.8%	50.0%	54.8%	71.0%	50.0%	41.9%	83.3%	83.9%	62.2%
Inversion Frequency $_{1600h}$	67.7%	35.7%	3.2%	0.0%	0.0%	0.0%	0.0%	0.0%	3.3%	3.2%	70.0%	83.9%	22.3%
Average Inversion Depth $_{0400h}$ (m)	572	478	284	278	274	271	343	284	314	222	509	841	389
Average Inversion Depth $_{1600h}$ (m)	713	899	446	-	-	-	-	-	464	242	527	817	587
Average Inversion Strength $_{0400h}$ (°C)	8.5	7.0	6.7	1.7	4.2	2.1	2.4	2.7	2.4	2.3	4.8	10.8	4.6
Average Inversion Strength $_{1600h}$ (°C)	7.6	8.0	1.1	-	-	-	-	-	0.4	1.4	4.5	8.3	4.5
Average Magnitude $_{0400h}$ (°C)	12.3	9.3	9.2	3.9	6.1	3.8	5.1	5.1	4.4	4.1	9.1	16.7	7.4
Average Magnitude $_{1600h}$ (°C)	12.3	14.4	4.3	-	-	-	-	-	3.5	1.9	9.3	13.6	8.5
Average Surface Temperature $_{0400h}$ (°C)	-22.4	-23.5	-15.6	-3.1	-0.4	4.4	7.9	5.5	4.0	-2.0	-15.3	-24.9	-7.1
Average Surface Temperature $_{1600h}$ (°C)	-21.6	-24.1	-7.0	-	-	-	-	-	7.2	0.6	-13.0	-22.3	-11.5
Average Monthly Temperature $_{ALL}$ (°C)	-20.8	-17.3	-9.5	-0.2	6.7	10.2	13.6	10.9	8.4	-1.1	-14.8	-21.5	-3.0
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	9.5	6.3	7.1	1.3	3.3	1.9	2.8	3.6	2.2	1.7	7.6	14.0	5.1
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	8.4	5.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	6.5	11.4	2.6
Impact of Inversion on Surface Temperature (°C)	8.9	5.7	3.6	0.6	1.7	0.9	1.4	1.8	1.2	0.9	7.0	12.7	3.9

1976	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	31	29	31	30	31	30	31	31	30	31	30	31	
Number of Soundings $_{1600h}$	31	29	31	30	31	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	83.9%	72.4%	80.6%	60.0%	54.8%	66.7%	58.1%	77.4%	53.3%	41.9%	46.7%	80.6%	64.7%
Inversion Frequency $_{1600h}$	83.9%	41.4%	16.1%	0.0%	0.0%	3.3%	0.0%	0.0%	0.0%	3.2%	26.7%	64.5%	19.9%
Average Inversion Depth $_{0400h}$ (m)	640	651	379	244	230	376	309	291	279	339	242	601	382
Average Inversion Depth $_{1600h}$ (m)	590	647	651	-	-	232	-	-	-	451	300	739	516
Average Inversion Strength $_{0400h}$ (°C)	9.0	7.9	5.1	3.5	2.3	3.4	4.0	3.5	2.9	2.3	2.0	5.4	4.3
Average Inversion Strength $_{1600h}$ (°C)	7.0	7.7	2.5	-	-	1.0	-	-	-	0.2	1.4	5.5	3.6
Average Magnitude $_{0400h}$ (°C)	14.0	12.5	8.1	6.0	4.1	6.8	6.4	6.0	5.1	4.8	4.4	10.2	7.4
Average Magnitude $_{1600h}$ (°C)	11.7	13.1	6.9	-	-	18.9	-	-	-	6.0	4.5	11.6	10.4
Average Surface Temperature $_{0400h}$ (°C)	-19.3	-19.2	-12.6	-4.0	-0.3	4.7	6.4	6.6	2.7	-1.6	-1.8	-11.8	-4.2
Average Surface Temperature $_{1600h}$ (°C)	-16.6	-16.5	-5.7	-	-	2.0	-	-	-	-2.1	-1.0	-11.8	-7.4
Average Monthly Temperature $_{ALL}$ (°C)	-15.6	-17.6	-7.6	1.2	5.5	11.7	13.3	12.7	7.8	1.6	-0.7	-11.6	0.1
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	11.8	9.1	6.5	3.6	2.2	4.5	3.7	4.6	2.7	2.0	2.0	8.3	5.1
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	9.8	5.4	1.1	0.0	0.0	0.6	0.0	0.0	0.0	0.2	1.2	7.5	2.2
Impact of Inversion on Surface Temperature (°C)	10.8	7.3	3.8	1.8	1.1	2.6	1.9	2.3	1.4	1.1	1.6	7.9	3.6

1977	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	31	28	31	30	31	30	31	31	30	31	30	31	
Number of Soundings $_{1600h}$	31	28	31	30	31	30	30	31	30	31	30	31	
Inversion Frequency $_{0400h}$	87.1%	60.7%	64.5%	30.0%	61.3%	70.0%	67.7%	71.0%	56.7%	45.2%	76.7%	83.9%	64.6%
Inversion Frequency $_{1600h}$	80.6%	14.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	53.3%	87.1%	19.6%
Average Inversion Depth $_{0400h}$ (m)	608	311	253	382	237	325	311	322	296	230	680	953	409
Average Inversion Depth $_{1600h}$ (m)	624	255	-	-	-	-	-	-	-	-	694	996	642
Average Inversion Strength $_{0400h}$ (°C)	5.0	2.3	3.0	3.4	2.8	2.9	3.0	5.2	3.2	1.3	5.3	14.5	4.3
Average Inversion Strength $_{1600h}$ (°C)	4.4	2.0	-	-	-	-	-	-	-	-	5.6	12.4	6.1
Average Magnitude $_{0400h}$ (°C)	9.8	6.1	5.5	6.1	4.8	6.1	5.6	7.4	5.1	4.1	11.0	21.8	7.8
Average Magnitude $_{1600h}$ (°C)	9.4	4.0	-	-	-	-	-	-	-	-	10.6	20.3	11.1
Average Surface Temperature $_{0400h}$ (°C)	-8.7	-6.2	-10.0	-2.4	-0.3	4.4	8.1	8.6	2.2	-0.3	-14.8	-28.3	-4.0
Average Surface Temperature $_{1600h}$ (°C)	-7.7	-6.4	-	-	-	-	-	-	-	-	-15.6	-25.3	-13.7
Average Monthly Temperature $_{ALL}$ (°C)	-8.1	-2.8	-6.7	2.2	6.4	11.2	13.3	15.0	7.0	2.2	-13.9	-26.1	0.0
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	8.5	3.7	3.6	1.8	3.0	4.2	3.8	5.3	2.9	1.9	8.4	18.3	5.4
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	7.6	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7	17.6	2.6
Impact of Inversion on Surface Temperature (°C)	8.0	2.1	1.8	0.9	1.5	2.1	1.9	2.6	1.4	0.9	7.0	18.0	4.0

1978	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	31	28	31	30	31	30	31	31	30	31	30	31	
Number of Soundings $_{1600h}$	31	28	31	30	31	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	93.5%	78.6%	54.8%	73.3%	51.6%	60.0%	51.6%	61.3%	60.0%	19.4%	73.3%	71.0%	62.4%
Inversion Frequency $_{1600h}$	93.5%	35.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.2%	43.3%	71.0%	20.6%
Average Inversion Depth $_{0400h}$ (m)	822	438	412	281	286	292	320	306	303	349	520	574	409
Average Inversion Depth $_{1600h}$ (m)	863	620	-	-	-	-	-	-	-	193	872	494	609
Average Inversion Strength $_{0400h}$ (°C)	10.6	6.2	4.0	3.2	2.8	3.3	3.3	3.3	4.0	2.4	5.6	5.8	4.5
Average Inversion Strength $_{1600h}$ (°C)	8.8	4.9	-	-	-	-	-	-	-	0.3	6.4	4.4	5.0
Average Magnitude $_{0400h}$ (°C)	17.2	10.1	7.7	5.9	5.0	6.0	5.8	5.7	6.4	4.7	9.3	10.8	7.9
Average Magnitude $_{1600h}$ (°C)	15.3	10.1	-	-	-	-	-	-	-	1.9	12.9	8.2	9.7
Average Surface Temperature $_{0400h}$ (°C)	-18.6	-13.1	-11.5	-4.9	0.0	4.7	8.6	7.1	1.2	-2.8	-11.5	-14.6	-4.6
Average Surface Temperature $_{1600h}$ (°C)	-16.7	-11.9	-	-	-	-	-	-	-	4.0	-10.9	-13.9	-9.9
Average Monthly Temperature $_{ALL}$ (°C)	-18.0	-9.9	-5.9	1.1	6.6	11.6	14.1	13.2	7.6	3.5	-10.2	-13.8	0.0
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	16.1	7.9	4.2	4.3	2.6	3.6	3.0	3.5	3.8	0.9	6.8	7.7	5.4
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	14.3	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	5.6	5.8	2.4
Impact of Inversion on Surface Temperature (°C)	15.2	5.7	2.1	2.2	1.3	1.8	1.5	1.7	1.9	0.5	6.2	6.7	3.9

1979	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	31	28	31	30	31	30	31	31	30	31	30	31	
Number of Soundings $_{1600h}$	31	28	31	30	31	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	87.1%	60.7%	64.5%	76.7%	48.4%	36.7%	41.9%	71.0%	60.0%	58.1%	63.3%	74.2%	61.9%
Inversion Frequency $_{1600h}$	83.9%	42.9%	12.9%	3.3%	0.0%	0.0%	0.0%	0.0%	0.0%	3.2%	43.3%	67.7%	21.4%
Average Inversion Depth $_{0400h}$ (m)	827	1026	484	331	323	301	296	308	253	316	536	608	467
Average Inversion Depth $_{1600h}$ (m)	778	705	770	764	-	-	-	-	-	112	552	646	618
Average Inversion Strength $_{0400h}$ (°C)	12.3	9.6	5.2	4.7	3.7	1.6	2.7	4.9	2.8	2.6	4.9	7.2	5.2
Average Inversion Strength $_{1600h}$ (°C)	10.8	4.5	7.0	9	-	-	-	-	-	0.1	4.9	6.3	6.0
Average Magnitude $_{0400h}$ (°C)	18.0	15.4	8.4	7.5	6.2	4.8	5.4	7.3	4.7	5.3	9.8	12.4	8.8
Average Magnitude $_{1600h}$ (°C)	16.8	9.1	12.7	14	-	-	-	-	-	2.4	10.1	12.3	11.0
Average Surface Temperature $_{0400h}$ (°C)	-22.4	-31.2	-10.8	-5.5	-0.1	4.6	7.0	6.7	2.9	-0.4	-6.2	-16.9	-6.0
Average Surface Temperature $_{1600h}$ (°C)	-20.4	-25.1	-9.0	-8	-	-	-	-	-	0.4	-3.9	-16.1	-11.8
Average Monthly Temperature $_{ALL}$ (°C)	-22.2	-28.0	-4.4	1.0	6.6	11.1	13.7	13.9	8.4	3.3	-3.6	-16.2	-1.4
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	15.7	9.4	5.4	5.7	3.0	1.8	2.3	5.2	2.8	3.1	6.2	9.2	5.8
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	14.1	3.9	1.6	0.5	0.0	0.0	0.0	0.0	0.0	0.1	4.4	8.4	2.7
Impact of Inversion on Surface Temperature (°C)	14.9	6.6	3.5	3.1	1.5	0.9	1.1	2.6	1.4	1.6	5.3	8.8	4.3

1980	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	31	29	31	30	31	30	31	31	30	31	30	31	
Number of Soundings $_{1600h}$	31	29	31	30	31	30	30	31	30	31	30	31	
Inversion Frequency $_{0400h}$	77.4%	79.3%	41.9%	30.0%	77.4%	66.7%	41.9%	48.4%	50.0%	48.4%	43.3%	83.9%	57.4%
Inversion Frequency $_{1600h}$	61.3%	48.3%	3.2%	3.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	13.3%	83.9%	17.8%
Average Inversion Depth $_{0400h}$ (m)	657	665	409	288	312	321	289	336	298	233	209	995	418
Average Inversion Depth $_{1600h}$ (m)	775	825	446	527	-	-	-	-	-	-	203	947	620
Average Inversion Strength $_{0400h}$ (°C)	7.3	7.5	4.0	2.1	3.8	3.1	3.0	3.9	2.5	1.4	2.0	14.0	4.5
Average Inversion Strength $_{1600h}$ (°C)	7.0	4.2	1.7	2	-	-	-	-	-	-	2.6	14.2	5.3
Average Magnitude $_{0400h}$ (°C)	11.9	12.6	7.9	4.3	6.2	6.0	5.1	6.4	5.1	3.2	4.6	20.0	7.8
Average Magnitude $_{1600h}$ (°C)	11.7	10.7	4.1	7	-	-	-	-	-	-	5.2	20.0	9.8
Average Surface Temperature $_{0400h}$ (°C)	-23.2	-12.6	-12.0	-1.6	-0.2	6.8	7.3	5.2	1.6	0.3	-3.2	-28.9	-5.0
Average Surface Temperature $_{1600h}$ (°C)	-21.5	-8.9	-6.3	-4	-	-	-	-	-	-	-4.1	-27.2	-12.1
Average Monthly Temperature $_{ALL}$ (°C)	-21.2	-8.2	-6.2	3.2	7.2	13.6	14.0	11.5	5.9	3.5	-3.3	-27.6	-0.6
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	9.2	10.0	3.3	1.3	4.8	4.0	2.1	3.1	2.5	1.6	2.0	16.8	5.1
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	7.2	5.2	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.7	16.7	2.5
Impact of Inversion on Surface Temperature (°C)	8.2	7.6	1.7	0.8	2.4	2.0	1.1	1.6	1.3	0.8	1.3	16.8	3.8

1981	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	31	28	31	20	30	30	31	31	29	28	30	30	
Number of Soundings $_{1600h}$	31	28	31	20	31	30	30	30	30	29	30	31	
Inversion Frequency $_{0400h}$	80.6%	82.1%	61.3%	70.0%	90.0%	60.0%	64.5%	51.6%	55.2%	35.7%	50.0%	90.0%	65.9%
Inversion Frequency $_{1600h}$	77.4%	60.7%	16.1%	0.0%	3.2%	0.0%	0.0%	3.3%	0.0%	3.4%	30.0%	67.7%	21.8%
Average Inversion Depth $_{0400h}$ (m)	320	390	236	180	284	266	229	261	270	326	285	451	291
Average Inversion Depth $_{1600h}$ (m)	319	365	188	-	160	-	-	429	-	423	252	520	332
Average Inversion Strength $_{0400h}$ (°C)	2.4	7.2	3.7	2.3	3.1	2.9	2.4	3.2	2.9	2.1	3.3	6.6	3.5
Average Inversion Strength $_{1600h}$ (°C)	2.4	5.8	2.5	-	2	-	-	0	-	1.8	1.4	6.5	2.8
Average Magnitude $_{0400h}$ (°C)	4.7	9.8	4.8	4.1	5.0	5.3	4.1	5.3	5.2	4.3	5.6	9.8	5.7
Average Magnitude $_{1600h}$ (°C)	5.0	8.9	5.1	-	1	-	-	2	-	4.1	3.2	9.4	4.9
Average Surface Temperature $_{0400h}$ (°C)	-4.6	-12.5	-5.3	-5.0	2.9	4.3	9.4	7.3	1.3	-1.9	-7.5	-16.3	-2.3
Average Surface Temperature $_{1600h}$ (°C)	-4.5	-9.1	2.5	-	17	-	-	15	-	1.7	-3.6	-16.7	0.3
Average Monthly Temperature $_{ALL}$ (°C)	-4.1	-11.4	-2.2	-2.1	8.9	10.6	14.4	12.9	6.5	1.7	-4.8	-16.3	1.2
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	3.8	8.1	2.9	2.9	4.5	3.2	2.6	2.7	2.9	1.5	2.8	8.8	3.9
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	3.9	5.4	0.8	0.0	0.0	0.0	0.0	0.1	0.0	0.1	1.0	6.4	1.5
Impact of Inversion on Surface Temperature (°C)	3.8	6.7	1.9	1.4	2.3	1.6	1.3	1.4	1.4	0.8	1.9	7.6	2.7

1982	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	30	28	31	30	31	30	31	30	30	31	30	31	
Number of Soundings $_{1600h}$	31	28	31	30	31	30	31	30	30	31	30	31	
Inversion Frequency $_{0400h}$	93.3%	78.6%	74.2%	60.0%	71.0%	80.0%	77.4%	73.3%	70.0%	61.3%	73.3%	90.3%	75.2%
Inversion Frequency $_{1600h}$	80.6%	53.6%	22.6%	0.0%	0.0%	0.0%	6.5%	0.0%	13.3%	12.9%	70.0%	90.3%	29.2%
Average Inversion Depth $_{0400h}$ (m)	652	419	345	260	190	295	244	243	267	164	382	445	325
Average Inversion Depth $_{1600h}$ (m)	651	616	313	-	-	-	134	-	185	278	382	377	367
Average Inversion Strength $_{0400h}$ (°C)	12.2	7.3	5.0	4.4	2.0	4.0	3.7	3.0	2.7	2.4	5.4	6.8	4.9
Average Inversion Strength $_{1600h}$ (°C)	10.6	6.8	1.3	-	-	-	2	-	0.5	1.1	5.8	5.2	4.1
Average Magnitude $_{0400h}$ (°C)	16.4	9.8	6.6	6.2	3.7	6.8	5.8	5.0	4.4	3.7	7.3	9.7	7.1
Average Magnitude $_{1600h}$ (°C)	13.9	11.0	3.1	-	-	-	3	-	1.5	2.3	8.1	7.6	6.3
Average Surface Temperature $_{0400h}$ (°C)	-32.8	-19.9	-13.9	-9.0	-0.2	5.7	8.8	6.8	4.3	-3.0	-13.2	-13.4	-6.7
Average Surface Temperature $_{1600h}$ (°C)	-31.5	-13.1	-13.3	-	-	-	17	-	14.1	-3.7	-11.9	-12.1	-6.8
Average Monthly Temperature $_{ALL}$ (°C)	-31.2	-18.1	-9.4	-2.2	5.4	12.8	15.0	11.5	8.6	-2.0	-11.3	-12.3	-2.8
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	15.3	7.7	4.9	3.7	2.6	5.4	4.5	3.7	3.1	2.3	5.4	8.7	5.6
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	11.2	5.9	0.7	0.0	0.0	0.0	0.2	0.0	0.2	0.3	5.6	6.8	2.6
Impact of Inversion on Surface Temperature (°C)	13.3	6.8	2.8	1.8	1.3	2.7	2.3	1.8	1.6	1.3	5.5	7.8	4.1

1983	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	31	28	31	30	31	30	31	31	30	31	30	31	
Number of Soundings $_{1600h}$	31	27	31	30	31	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	87.1%	100.0%	87.1%	66.7%	77.4%	70.0%	64.5%	61.3%	53.3%	51.6%	86.7%	96.8%	75.2%
Inversion Frequency $_{1600h}$	90.3%	74.1%	19.4%	6.7%	0.0%	0.0%	0.0%	6.5%	6.7%	9.7%	56.7%	100.0%	30.8%
Average Inversion Depth $_{0400h}$ (m)	405	401	287	217	200	231	196	164	207	257	320	450	278
Average Inversion Depth $_{1600h}$ (m)	440	331	233	49	-	-	-	64	53	108	461	561	256
Average Inversion Strength $_{0400h}$ (°C)	8.5	5.7	6.2	4.6	3.0	3.5	3.2	1.9	3.5	1.7	4.1	12.1	4.8
Average Inversion Strength $_{1600h}$ (°C)	7.8	3.3	0.8	1	-	-	-	0	0.4	1.6	4.3	11.7	3.4
Average Magnitude $_{0400h}$ (°C)	11.2	8.7	8.2	6.5	4.6	5.5	5.1	3.2	5.0	3.7	5.8	13.7	6.8
Average Magnitude $_{1600h}$ (°C)	10.8	5.2	1.5	1	-	-	-	1	0.5	2.8	7.5	14.2	4.9
Average Surface Temperature $_{0400h}$ (°C)	-19.0	-13.6	-13.0	-3.5	1.9	6.2	7.5	7.0	-1.3	-2.2	-9.5	-24.2	-5.3
Average Surface Temperature $_{1600h}$ (°C)	-17.2	-10.4	-5.7	6	-	-	-	15	2.5	5.0	-8.5	-22.6	-4.0
Average Monthly Temperature $_{ALL}$ (°C)	-19.4	-11.7	-7.5	2.3	8.0	13.0	13.7	11.6	4.6	0.4	-9.3	-23.9	-1.5
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	9.8	8.7	7.1	4.3	3.6	3.9	3.3	2.0	2.7	1.9	5.0	13.2	5.5
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	9.8	3.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	4.3	14.2	2.7
Impact of Inversion on Surface Temperature (°C)	9.8	6.3	3.7	2.2	1.8	1.9	1.7	1.0	1.3	1.1	4.6	13.7	4.1

1984	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	30	29	31	30	31	30	31	31	30	31	30	31	
Number of Soundings $_{1600h}$	30	29	31	30	31	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	83.3%	89.7%	58.1%	73.3%	90.3%	56.7%	80.6%	54.8%	73.3%	54.8%	83.3%	87.1%	73.8%
Inversion Frequency $_{1600h}$	80.0%	24.1%	6.5%	3.3%	0.0%	0.0%	0.0%	3.2%	0.0%	12.9%	80.0%	74.2%	23.7%
Average Inversion Depth $_{0400h}$ (m)	413	223	197	186	209	218	228	309	265	216	344	447	271
Average Inversion Depth $_{1600h}$ (m)	486	330	507	19	-	-	-	177	-	224	227	485	307
Average Inversion Strength $_{0400h}$ (°C)	6.6	3.1	2.0	2.6	3.1	3.7	3.2	3.8	3.8	3.0	3.5	7.6	3.8
Average Inversion Strength $_{1600h}$ (°C)	6.5	2.6	2.3	1	-	-	-	1	-	1.7	2.4	7.3	3.1
Average Magnitude $_{0400h}$ (°C)	9.6	5.1	3.4	4.2	5.2	5.8	4.9	6.1	6.0	4.3	5.9	9.6	5.8
Average Magnitude $_{1600h}$ (°C)	9.3	4.2	8.9	0	-	-	-	1	-	3.0	3.5	9.9	5.1
Average Surface Temperature $_{0400h}$ (°C)	-13.4	-8.4	-2.7	-3.0	0.8	3.9	5.3	6.3	0.9	-6.3	-11.2	-19.0	-3.9
Average Surface Temperature $_{1600h}$ (°C)	-13.4	-8.8	3.2	3	-	-	-	10	-	-0.6	-9.2	-18.3	-4.3
Average Monthly Temperature $_{ALL}$ (°C)	-12.8	-6.3	0.1	2.6	6.8	11.3	12.5	11.8	6.4	-1.9	-10.5	-18.2	0.2
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	8.0	4.5	2.0	3.1	4.7	3.3	4.0	3.3	4.4	2.4	4.9	8.4	4.4
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	7.5	1.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.4	2.8	7.3	1.6
Impact of Inversion on Surface Temperature (°C)	7.7	2.8	1.3	1.6	2.3	1.7	2.0	1.7	2.2	1.4	3.9	7.9	3.0

1985	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	31	27	31	29	31	30	31	31	30	31	30	31	
Number of Soundings $_{1600h}$	31	28	31	29	31	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	80.6%	77.8%	71.0%	58.6%	67.7%	50.0%	64.5%	74.2%	70.0%	61.3%	90.0%	83.9%	70.8%
Inversion Frequency $_{1600h}$	80.6%	53.6%	9.7%	0.0%	3.2%	3.3%	6.5%	3.2%	0.0%	19.4%	70.0%	77.4%	27.2%
Average Inversion Depth $_{0400h}$ (m)	291	379	211	136	253	270	260	225	279	220	347	406	273
Average Inversion Depth $_{1600h}$ (m)	286	464	103	-	151	137	276	127	-	337	311	455	265
Average Inversion Strength $_{0400h}$ (°C)	3.4	7.9	3.0	1.6	3.4	3.5	3.5	3.2	3.2	2.8	6.1	6.5	4.0
Average Inversion Strength $_{1600h}$ (°C)	2.6	6.2	0.6	-	0	1.6	1	1	-	2.3	5.9	5.8	2.7
Average Magnitude $_{0400h}$ (°C)	5.1	9.6	4.9	3.1	5.4	5.5	5.9	5.1	4.7	4.3	7.9	8.8	5.9
Average Magnitude $_{1600h}$ (°C)	4.2	8.7	1.1	-	0	1.5	3	2	-	4.4	7.4	8.6	4.1
Average Surface Temperature $_{0400h}$ (°C)	-6.0	-18.6	-9.1	-4.6	0.2	3.3	8.1	4.9	1.9	-5.9	-19.4	-9.5	-4.6
Average Surface Temperature $_{1600h}$ (°C)	-4.3	-17.4	-9.8	-	4	6.6	15	10	-	-7.5	-17.7	-9.3	-3.0
Average Monthly Temperature $_{ALL}$ (°C)	-4.7	-18.2	-6.0	-0.9	6.2	9.7	13.9	11.2	6.9	-2.7	-18.2	-6.7	-0.8
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	4.1	7.5	3.5	1.8	3.6	2.8	3.8	3.8	3.3	2.6	7.1	7.4	4.3
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	3.4	4.7	0.1	0.0	0.0	0.0	0.2	0.1	0.0	0.9	5.1	6.7	1.8
Impact of Inversion on Surface Temperature (°C)	3.8	6.1	1.8	0.9	1.8	1.4	2.0	1.9	1.6	1.8	6.1	7.0	3.0

1986	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	30	28	31	30	31	29	20	31	30	31	30	31	
Number of Soundings $_{1600h}$	31	28	31	30	31	30	21	31	30	31	30	31	
Inversion Frequency $_{0400h}$	76.7%	85.7%	74.2%	76.7%	64.5%	79.3%	70.0%	51.6%	73.3%	51.6%	73.3%	83.9%	71.7%
Inversion Frequency $_{1600h}$	67.7%	64.3%	22.6%	0.0%	0.0%	0.0%	0.0%	0.0%	6.7%	16.1%	56.7%	87.1%	26.8%
Average Inversion Depth $_{0400h}$ (m)	255	350	246	230	241	287	348	229	229	314	339	211	273
Average Inversion Depth $_{1600h}$ (m)	255	346	386	-	-	-	-	-	540	381	286	287	354
Average Inversion Strength $_{0400h}$ (°C)	3.4	6.8	5.1	4.3	2.4	3.9	3.6	2.1	4.9	3.2	4.3	3.1	3.9
Average Inversion Strength $_{1600h}$ (°C)	2.6	3.9	2.9	-	-	-	-	-	0.6	1.9	3.6	2.7	2.6
Average Magnitude $_{0400h}$ (°C)	5.3	8.9	6.8	6.2	4.5	6.6	7.0	3.8	6.7	5.6	5.9	4.2	6.0
Average Magnitude $_{1600h}$ (°C)	4.5	5.9	5.5	-	-		-	-	2.8	4.6	5.0	4.9	4.7
Average Surface Temperature $_{0400h}$ (°C)	-9.7	-16.4	-11.4	-9.6	-0.4	4.3	8.7	5.5	1.9	-1.7	-13.7	-5.7	-4.0
Average Surface Temperature $_{1600h}$ (°C)	-8.1	-7.4	-5.6	-	-		-	-	1.8	4.9	-11.6	-4.8	-4.4
Average Monthly Temperature $_{ALL}$ (°C)	-7.8	-12.8	-7.3	-4.5	5.4	11.4	14.3	11.1	6.6	2.5	-11.5	-5.1	0.2
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	4.1	7.6	5.1	4.7	2.9	5.2	4.9	2.0	4.9	2.9	4.3	3.5	4.3
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	3.0	3.8	1.2	0.0	0.0	0.0	0.0	0.0	0.2	0.7	2.9	4.2	1.3
Impact of Inversion on Surface Temperature (°C)	3.6	5.7	3.1	2.4	1.4	2.6	2.5	1.0	2.5	1.8	3.6	3.9	2.8

1987	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	31	28	31	30	31	30	31	31	29	31	29	31	
Number of Soundings $_{1600h}$	31	28	31	30	31	30	31	29	29	31	30	31	
Inversion Frequency $_{0400h}$	90.3%	78.6%	80.6%	53.3%	64.5%	73.3%	64.5%	80.6%	37.9%	48.4%	62.1%	80.6%	67.9%
Inversion Frequency $_{1600h}$	74.2%	53.6%	6.5%	0.0%	0.0%	0.0%	0.0%	3.4%	0.0%	3.2%	33.3%	77.4%	21.0%
Average Inversion Depth $_{0400h}$ (m)	377	280	300	166	209	156	237	256	187	299	299	345	259
Average Inversion Depth $_{1600h}$ (m)	300	246	667	-	-	-	-	182	-	276	256	307	319
Average Inversion Strength $_{0400h}$ (°C)	4.6	2.4	6.1	1.8	2.8	2.1	2.9	4.1	1.8	1.8	2.4	5.3	3.2
Average Inversion Strength $_{1600h}$ (°C)	3.5	1.8	3.3	-	-	-	-	1	-	1.3	1.6	4.5	2.4
Average Magnitude $_{0400h}$ (°C)	7.1	4.2	7.8	3.5	4.5	3.4	4.9	6.2	3.3	3.6	4.4	8.1	5.1
Average Magnitude $_{1600h}$ (°C)	5.8	3.2	8.8	-	-		-	1		2.7	3.5	6.5	4.4
Average Surface Temperature $_{0400h}$ (°C)	-10.4	-7.5	-14.5	-2.9	0.2	5.4	9.1	6.3	3.3	-0.6	-5.5	-11.2	-2.4
Average Surface Temperature $_{1600h}$ (°C)	-8.6	-5.7	-8.2	-	-		-	8		4.5	-1.9	-10.4	-3.2
Average Monthly Temperature $_{ALL}$ (°C)	-9.0	-6.8	-10.0	1.4	6.5	10.5	15.0	11.7	8.0	2.8	-3.3	-9.7	1.4
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	6.4	3.3	6.3	1.8	2.9	2.5	3.2	5.0	1.3	1.8	2.7	6.5	3.6
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	4.3	1.7	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.2	5.1	1.1
Impact of Inversion on Surface Temperature (°C)	5.4	2.5	3.4	0.9	1.4	1.2	1.6	2.5	0.6	0.9	1.9	5.8	2.4

1988	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	26	29	31	30	31	30	31	31	30	30	30	30	
Number of Soundings $_{1600h}$	29	29	31	30	31	30	31	31	29	31	30	30	
Inversion Frequency $_{0400h}$	100.0%	79.3%	67.7%	66.7%	61.3%	60.0%	58.1%	58.1%	76.7%	46.7%	60.0%	73.3%	67.3%
Inversion Frequency $_{1600h}$	89.7%	41.4%	12.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	25.8%	36.7%	63.3%	22.5%
Average Inversion Depth $_{0400h}$ (m)	538	413	250	226	259	297	245	294	243	344	311	406	319
Average Inversion Depth $_{1600h}$ (m)	574	352	178	-	-	-	-	-	-	254	420	305	347
Average Inversion Strength $_{0400h}$ (°C)	13.1	5.0	3.5	2.9	3.2	3.0	2.3	2.2	3.2	3.7	3.4	5.9	4.3
Average Inversion Strength $_{1600h}$ (°C)	10.6	4.6	2.0	-	-	-	-	-	-	2.6	2.9	4.1	4.5
Average Magnitude $_{0400h}$ (°C)	16.7	7.4	5.6	4.7	5.1	5.5	4.1	4.3	5.2	6.3	5.2	8.3	6.5
Average Magnitude $_{1600h}$ (°C)	14.2	7.0	2.4	-	-		-	-		4.4	6.0	5.8	6.6
Average Surface Temperature $_{0400h}$ (°C)	-20.8	-12.6	-7.2	-2.7	0.1	5.1	7.8	7.5	1.7	-3.6	-11.3	-13.1	-4.1
Average Surface Temperature $_{1600h}$ (°C)	-17.9	-12.4	-2.9	-	-		-	-		-1.1	-10.0	-12.2	-9.4
Average Monthly Temperature $_{ALL}$ (°C)	-18.5	-9.9	-3.0	2.0	7.1	11.8	12.6	12.2	6.0	0.8	-7.9	-10.6	0.2
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	16.7	5.8	3.8	3.1	3.2	3.3	2.4	2.5	4.0	2.9	3.1	6.1	4.7
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	12.7	2.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.1	2.2	3.7	1.9
Impact of Inversion on Surface Temperature (°C)	14.7	4.4	2.1	1.6	1.6	1.7	1.2	1.2	2.0	2.0	2.7	4.9	3.3

1989	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	31	27	31	30	31	30	31	29	30	31	30	31	
Number of Soundings $_{1600h}$	30	27	31	30	31	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	67.7%	96.3%	64.5%	96.7%	61.3%	66.7%	74.2%	75.9%	66.7%	41.9%	73.3%	80.6%	72.2%
Inversion Frequency $_{1600h}$	73.3%	77.8%	19.4%	0.0%	0.0%	3.3%	3.2%	0.0%	0.0%	16.1%	60.0%	77.4%	27.5%
Average Inversion Depth $_{0400h}$ (m)	523	623	328	252	254	194	282	372	272	252	259	237	321
Average Inversion Depth $_{1600h}$ (m)	384	691	252	-	-	161	226	-	-	130	335	238	302
Average Inversion Strength $_{0400h}$ (°C)	9.5	12.4	7.6	2.5	3.9	3.0	4.0	4.0	3.4	2.3	4.5	3.6	5.1
Average Inversion Strength $_{1600h}$ (°C)	7.6	10.2	2.0	-	-	0.6	1	-	-	1.9	4.3	1.7	3.6
Average Magnitude $_{0400h}$ (°C)	13.4	15.7	9.5	4.6	5.8	5.0	6.7	6.9	5.1	3.6	6.5	5.0	7.3
Average Magnitude $_{1600h}$ (°C)	10.1	14.3	3.7	-	-	1.7	0	-	-	1.3	6.3	3.2	5.1
Average Surface Temperature $_{0400h}$ (°C)	-21.7	-20.5	-19.5	-1.6	2.2	5.6	9.5	8.8	4.4	-3.2	-13.1	-7.6	-4.7
Average Surface Temperature $_{1600h}$ (°C)	-19.1	-14.1	-8.9	-	-	11.8	16	-	-	-2.5	-14.5	-5.5	-4.5
Average Monthly Temperature $_{ALL}$ (°C)	-21.7	-17.6	-11.9	3.2	9.1	12.6	16.0	15.1	8.6	-0.3	-12.2	-6.8	-0.5
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	9.1	15.1	6.2	4.4	3.6	3.3	5.0	5.2	3.4	1.5	4.8	4.0	5.5
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	7.4	11.1	0.7	0.0	0.0	0.1	0.0	0.0	0.0	0.2	3.8	2.5	2.1
Impact of Inversion on Surface Temperature (°C)	8.2	13.1	3.4	2.2	1.8	1.7	2.5	2.6	1.7	0.9	4.3	3.2	3.8

1991	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	31	28	31	30	-	30	31	30	30	31	30	31	
Number of Soundings $_{1600h}$	31	28	30	30	-	30	31	31	30	31	30	31	
Inversion Frequency $_{0400h}$	87.1%	82.1%	77.4%	83.3%	-	86.7%	54.8%	50.0%	60.0%	71.0%	83.3%	96.8%	75.7%
Inversion Frequency $_{1600h}$	90.3%	46.4%	13.3%	0.0%	-	6.7%	0.0%	0.0%	0.0%	19.4%	66.7%	71.0%	28.5%
Average Inversion Depth $_{0400h}$ (m)	497	284	228	223	-	257	185	244	156	190	306	300	261
Average Inversion Depth $_{1600h}$ (m)	470	229	171		-	95	-	-	-	285	320	344	273
Average Inversion Strength $_{0400h}$ (°C)	11.5	5.3	5.6	2.4	-	3.2	2.5	2.8	2.0	2.1	4.9	4.7	4.3
Average Inversion Strength $_{1600h}$ (°C)	8.4	4.3	1.5		-	1.4	-	-	-	0.7	3.4	4.9	3.5
Average Magnitude $_{0400h}$ (°C)	14.4	7.2	7.4	4.3	-	5.5	3.9	4.8	3.1	3.5	7.0	6.5	6.2
Average Magnitude $_{1600h}$ (°C)	10.9	5.5	2.6		-	2.6	-	-	-	1.4	6.0	7.1	5.2
Average Surface Temperature $_{0400h}$ (°C)	-20.7	-9.4	-13.2	-1.9	-	6.3	8.3	6.8	4.4	-3.7	-10.1	-11.3	-4.0
Average Surface Temperature $_{1600h}$ (°C)	-17.7	-5.6	-2.6		-	18.2	-	-	-	-3.2	-7.3	-12.1	-4.3
Average Monthly Temperature $_{ALL}$ (°C)	-18.8	-7.4	-7.2	2.6	8.3	12.7	13.3	11.7	8.4	-2.1	-9.2	-11.2	0.1
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	12.5	5.9	5.8	3.6	-	3.4	2.6	1.6	2.1	4.9	5.4	6.0	4.9
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	9.8	2.6	0.3	0.0	-	0.2	0.0	0.0	0.0	0.3	4.0	5.0	2.0
Impact of Inversion on Surface Temperature (°C)	11.2	4.2	3.1	1.8	-	1.8	1.3	0.8	1.1	2.6	4.7	5.5	2.5

1992	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	31	28	31	30	31	30	31	31	30	31	29	26	
Number of Soundings $_{1600h}$	31	29	31	30	31	30	31	31	29	31	29	27	
Inversion Frequency $_{0400h}$	83.9%	78.6%	58.1%	63.3%	35.5%	80.0%	64.5%	64.5%	33.3%	64.5%	75.9%	92.3%	66.2%
Inversion Frequency $_{1600h}$	77.4%	51.7%	3.2%	0.0%	3.2%	0.0%	0.0%	0.0%	10.3%	29.0%	58.6%	88.9%	26.9%
Average Inversion Depth $_{0400h}$ (m)	297	287	221	242	159	263	243	258	169	204	161	437	245
Average Inversion Depth $_{1600h}$ (m)	264	306	701	-	64	-	-	-	304	154	224	365	298
Average Inversion Strength $_{0400h}$ (°C)	3.9	3.7	2.5	2.3	2.4	4.3	2.3	2.3	1.6	2.6	2.8	8.5	3.3
Average Inversion Strength $_{1600h}$ (°C)	3.1	2.9	4.8	-	1	-	-	-	1.5	1.1	2.5	6.7	2.9
Average Magnitude $_{0400h}$ (°C)	5.9	5.5	4.3	4.3	3.6	6.8	4.4	4.2	2.9	4.0	3.9	11.2	5.1
Average Magnitude $_{1600h}$ (°C)	5.2	4.4	6.0	-	1	-	-	-	2.6	1.2	4.5	8.4	4.1
Average Surface Temperature $_{0400h}$ (°C)	-9.1	-14.5	-8.6	-3.3	0.9	5.3	9.0	6.7	-0.9	-2.9	-5.1	-20.7	-3.6
Average Surface Temperature $_{1600h}$ (°C)	-8.6	-10.2	-16.6	-	5	-	-	-	0.3	-2.5	-5.5	-17.6	-6.9
Average Monthly Temperature $_{ALL}$ (°C)	-8.2	-11.6	-3.3	0.1	5.8	12.3	14.2	12.3	2.6	-1.8	-4.6	-18.7	-0.1
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	5.0	4.3	2.5	2.7	1.3	5.5	2.8	2.7	1.0	2.6	2.9	10.3	3.6
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	4.0	2.3	0.2	0.0	0.0	0.0	0.0	0.0	0.3	0.4	2.7	7.4	1.4
Impact of Inversion on Surface Temperature (°C)	4.5	3.3	1.3	1.4	0.7	2.7	1.4	1.3	0.6	1.5	2.8	8.9	2.5

1993	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	31	27	28	28	28	26	31	29	30	30	29	28	
Number of Soundings $_{1600h}$	31	28	30	28	29	30	31	30	29	30	30	28	
Inversion Frequency $_{0400h}$	90.3%	88.9%	89.3%	75.0%	82.1%	84.6%	74.2%	79.3%	70.0%	83.3%	72.4%	85.7%	81.3%
Inversion Frequency $_{1600h}$	87.1%	71.4%	3.3%	10.7%	0.0%	20.0%	6.5%	6.7%	3.4%	36.7%	60.0%	92.9%	33.2%
Average Inversion Depth $_{0400h}$ (m)	521	414	215	233	199	254	244	224	244	199	305	228	273
Average Inversion Depth $_{1600h}$ (m)	454	253	213	-	53	268	-	-	-	220	247	201	238
Average Inversion Strength $_{0400h}$ (°C)	9.9	7.1	3.5	3.3	3.1	3.0	3.1	3.2	3.5	2.5	4.5	4.4	4.3
Average Inversion Strength $_{1600h}$ (°C)	*7.9*	*3.9*	*0.4*	-	1	*3.4*	-	-	-	1.1	3.3	2.5	*2.9*
Average Magnitude $_{0400h}$ (°C)	12.5	9.4	5.0	5.6	4.7	5.1	5.2	4.9	5.5	3.6	6.3	5.5	6.1
Average Magnitude $_{1600h}$ (°C)	10.2	5.3	1.3	-	11	6.1	-	-	-	1.7	4.9	3.6	5.5
Average Surface Temperature $_{0400h}$ (°C)	-19.7	-14.2	-8.3	-1.8	2.9	6.3	9.1	7.1	3.1	1.4	-8.1	-8.6	-2.6
Average Surface Temperature $_{1600h}$ (°C)	-17.7	-9.9	1.6	-	13	15.9	-	-	-	3.9	-4.7	-6.4	-0.5
Average Monthly Temperature $_{ALL}$ (°C)	-17.7	-11.9	-4.9	3.5	9.5	12.7	14.4	12.7	8.2	2.4	-6.5	-8.1	1.2
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	11.3	8.4	4.5	4.2	3.9	4.3	3.9	3.9	3.8	3.0	4.6	4.7	5.0
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	8.8	3.8	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.6	2.9	3.3	1.7
Impact of Inversion on Surface Temperature (°C)	10.1	6.1	2.3	2.1	1.9	2.8	1.9	1.9	1.9	1.8	3.7	4.0	3.4

1994	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	30	27	-	30	30	30	31	31	22	31	30	30	
Number of Soundings $_{1600h}$	31	28	-	30	31	29	30	31	22	29	30	30	
Inversion Frequency $_{0400h}$	76.7%	85.2%	-	66.7%	80.0%	83.3%	74.2%	83.9%	86.4%	74.2%	76.7%	90.0%	79.7%
Inversion Frequency $_{1600h}$	71.0%	53.6%	-	0.0%	0.0%	24.1%	0.0%	0.0%	9.1%	13.8%	53.3%	83.3%	28.0%
Average Inversion Depth $_{0400h}$ (m)	442	508	-	228	177	191	248	340	171	161	249	397	283
Average Inversion Depth $_{1600h}$ (m)	487	441	-	-	-	5	-	-	96	74	337	443	269
Average Inversion Strength $_{0400h}$ (°C)	7.9	7.7	-	3.5	2.2	2.7	2.9	4.6	2.4	1.6	3.6	7.2	4.2
Average Inversion Strength $_{1600h}$ (°C)	6.7	6.1	-	-	-	0.9	-	-	0.2	0.1	3.0	6.6	3.4
Average Magnitude $_{0400h}$ (°C)	10.5	9.8	-	5.2	3.6	4.4	4.8	7.4	4.0	2.9	5.2	9.3	6.1
Average Magnitude $_{1600h}$ (°C)	9.7	7.6	-	-	-	0.1	-	-	0.5	0.5	5.1	9.0	4.6
Average Surface Temperature $_{0400h}$ (°C)	-17.5	-25.2	-	-1.1	2.2	6.3	9.2	10.7	2.6	-0.7	-13.3	-16.2	-3.9
Average Surface Temperature $_{1600h}$ (°C)	-15.2	-16.8	-	-	-	21.2	-	-	9.1	4.6	-12.4	-14.4	-3.4
Average Monthly Temperature $_{ALL}$ (°C)	-17.0	-22.2	-3.1	3.6	7.6	12.5	15.5	16.8	6.8	1.6	-13.2	-15.2	-0.5
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	8.0	8.3	0.0	2.4	3.5	4.0	5.5	3.4	2.5	3.9	7.1	5.5	4.5
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	6.9	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.7	7.5	1.8
Impact of Inversion on Surface Temperature (°C)	7.4	6.2	0.0	1.2	1.8	2.0	2.7	1.7	1.3	2.0	4.9	6.5	3.1

1995	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	30	28	29	30	31	29	30	20	30	31	30	27	
Number of Soundings $_{1600h}$	31	27	28	28	31	28	30	22	30	31	30	31	
Inversion Frequency $_{0400h}$	100.0%	39.3%	51.7%	96.7%	93.5%	93.1%	73.3%	75.0%	80.0%	77.4%	66.7%	92.6%	78.3%
Inversion Frequency $_{1600h}$	93.5%	37.0%	14.3%	0.0%	0.0%	3.6%	0.0%	0.0%	3.3%	9.7%	56.7%	71.0%	24.1%
Average Inversion Depth $_{0400h}$ (m)	441	224	258	222	214	193	185	209	232	194	221	290	240
Average Inversion Depth $_{1600h}$ (m)	484	177	180	-	-	194	-	-	87	178	251	378	241
Average Inversion Strength $_{0400h}$ (°C)	9.5	3.6	5.8	2.7	3.7	3.3	1.5	2.4	4.2	2.5	3.4	5.9	4.0
Average Inversion Strength $_{1600h}$ (°C)	8.6	1.6	3.4	-	-	1.5	-	-	0.1	0.7	2.6	6.0	3.1
Average Magnitude $_{0400h}$ (°C)	11.9	5.0	7.6	4.5	5.5	4.9	2.9	3.9	5.8	4.0	4.6	7.7	5.7
Average Magnitude $_{1600h}$ (°C)	11.5	2.8	3.8	-	-	2.1	-	-	0.5	2.0	3.6	8.3	4.3
Average Surface Temperature $_{0400h}$ (°C)	-15.9	-8.4	-11.1	-1.2	3.7	6.8	10.5	7.8	5.2	-1.6	-13.1	-15.3	-2.7
Average Surface Temperature $_{1600h}$ (°C)	-12.8	-3.2	-3.2	-	-	15.6	-	-	21.4	-0.4	-8.8	-13.6	-0.6
Average Monthly Temperature $_{ALL}$ (°C)	-14.9	-12.0	-10.4	3.3	-	13.6	15.0	11.6	10.5	1.1	-11.8	-15.8	-
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	11.9	2.0	2.3	5.3	4.6	2.7	2.8	4.3	3.2	3.6	5.2	5.3	4.4
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	10.8	1.0	0.5	0.0	0.0	0.1	0.0	0.0	0.0	0.2	2.0	5.9	1.7
Impact of Inversion on Surface Temperature (°C)	11.4	1.5	1.4	2.6	2.3	1.4	1.4	2.2	1.6	1.9	3.6	5.6	3.1

1996	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	28	29	31	30	31	30	31	30	27	30	30	29	
Number of Soundings $_{1600h}$	28	28	31	30	31	30	31	31	29	30	30	31	
Inversion Frequency $_{0400h}$	85.7%	62.1%	83.9%	93.3%	80.6%	76.7%	83.9%	73.3%	74.1%	60.0%	90.0%	100.0%	80.3%
Inversion Frequency $_{1600h}$	85.7%	35.7%	16.1%	0.0%	0.0%	0.0%	0.0%	3.2%	3.4%	26.7%	93.3%	90.3%	29.5%
Average Inversion Depth $_{0400h}$ (m)	839	399	318	176	185	222	158	204	175	247	319	401	304
Average Inversion Depth $_{1600h}$ (m)	588	485	324	-	-	-	-	226	34	369	228	374	329
Average Inversion Strength $_{0400h}$ (°C)	17.9	5.5	5.0	3.0	3.5	3.0	2.9	2.9	2.5	2.6	7.1	7.9	5.3
Average Inversion Strength $_{1600h}$ (°C)	12.5	5.3	5.0	-	-	-	-	2	0.1	3.3	3.7	6.4	4.7
Average Magnitude $_{0400h}$ (°C)	21.6	7.4	6.8	4.4	5.4	5.4	4.2	4.6	4.0	4.2	8.7	10.1	7.2
Average Magnitude $_{1600h}$ (°C)	14.9	6.2	5.9	-	-	-	-	2	0.4	5.1	5.0	8.7	6.1
Average Surface Temperature $_{0400h}$ (°C)	-33.7	-14.0	-12.0	-4.6	0.5	5.7	8.3	5.6	2.5	-5.9	-17.8	-20.3	-7.1
Average Surface Temperature $_{1600h}$ (°C)	-30.0	-10.8	-3.3	-	-	-	-	9	4.0	-4.6	-12.5	-18.2	-8.2
Average Monthly Temperature $_{ALL}$ (°C)	-	-	-	-	-	-	-	-	-	-	-	-	-
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	18.5	4.6	3.7	5.1	4.3	3.3	3.9	2.9	3.1	5.2	9.1	7.2	5.9
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	12.8	2.2	1.0	0.0	0.0	0.0	0.0	0.1	0.0	1.3	4.7	7.9	2.5
Impact of Inversion on Surface Temperature (°C)	15.6	3.4	2.3	2.5	2.2	1.6	1.9	1.5	1.5	3.3	6.9	7.5	4.2

1997	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	30	27	30	28	30	30	31	19	17	29	28		
Number of Soundings $_{1600h}$	31	28	31	28	31	30	31	19	18	30	30		
Inversion Frequency $_{0400h}$	96.7%	81.5%	73.3%	82.1%	83.3%	83.3%	83.9%	94.7%	94.1%	82.8%	96.4%		86.6%
Inversion Frequency $_{1600h}$	93.5%	64.3%	6.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	13.3%	66.7%		22.2%
Average Inversion Depth $_{0400h}$ (m)	614	241	189	192	172	168	173	176	174	152	261		228
Average Inversion Depth $_{1600h}$ (m)	404	216	215	-	-	-	-	-	-	376	265		295
Average Inversion Strength $_{0400h}$ (°C)	9.6	3.0	3.6	3.5	3.9	3.1	1.9	3.0	2.9	2.3	3.4		3.7
Average Inversion Strength $_{1600h}$ (°C)	6.2	1.7	0.5	-	-	-	-	-	-	3.8	2.9		3.0
Average Magnitude $_{0400h}$ (°C)	12.8	5.0	5.0	5.2	5.5	4.5	3.3	4.2	4.6	3.5	5.2		5.3
Average Magnitude $_{1600h}$ (°C)	8.2	3.2	1.2	-	-	-	-	-	-	5.2	4.7		4.5
Average Surface Temperature $_{0400h}$ (°C)	-21.1	-7.7	-13.8	-2.8	0.9	6.9	9.5	9.3	5.2	-4.7	-5.9		-2.2
Average Surface Temperature $_{1600h}$ (°C)	-19.7	-4.2	-3.6	-	-	-	-	-	-	-3.5	-5.2		-7.2
Average Monthly Temperature $_{ALL}$ (°C)	-	-	-	-	-	-	-	-	-	-	-	-	-
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	12.3	4.0	3.8	4.6	3.8	2.7	3.6	4.3	3.3	4.3	-	-	4.7
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	7.6	2.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.7	3.1	-	1.2
Impact of Inversion on Surface Temperature (°C)	10.0	3.1	1.9	2.3	1.9	1.4	1.8	2.2	1.6	2.5	1.6	0.0	2.5

1998	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	16	1	16	19	31	27	30	30	27	31	30	30	
Number of Soundings $_{1600h}$	18	26	26	21	30	30	30	31	27	31	29	30	
Inversion Frequency $_{0400h}$	93.8%	100.0%	75.0%	73.7%	64.5%	88.9%	80.0%	83.3%	96.3%	51.6%	60.0%	76.7%	78.6%
Inversion Frequency $_{1600h}$	83.3%	50.0%	3.8%	0.0%	0.0%	0.0%	0.0%	0.0%	22.2%	32.3%	58.6%	80.0%	27.5%
Average Inversion Depth $_{0400h}$ (m)	505	307	198	154	161	144	112	158	176	210	251	332	226
Average Inversion Depth $_{1600h}$ (m)	594	241	608	-	-	-	-	-	95	89	288	346	323
Average Inversion Strength $_{0400h}$ (°C)	8.6	5.6	4.4	1.7	3.4	3.0	2.8	3.3	3.1	3.1	3.5	6.1	4.1
Average Inversion Strength $_{1600h}$ (°C)	7.4	3.3	3.3	-	-	-	-	-	1.9	1.4	4.0	5.0	3.8
Average Magnitude $_{0400h}$ (°C)	11.4	9.6	5.9	3.3	4.4	4.3	4.1	4.7	4.4	4.3	4.4	7.6	5.7
Average Magnitude $_{1600h}$ (°C)	10.4	4.6	5.4	-	-	-	-	-	2.5	1.7	5.0	6.7	5.2
Average Surface Temperature $_{0400h}$ (°C)	-28.4	-8.4	-5.3	-2.1	3.7	7.9	8.9	6.0	1.8	-4.5	-10.3	-17.9	-4.0
Average Surface Temperature $_{1600h}$ (°C)	-19.5	-6.1	-6.4	-	-	-	-	-	5.0	-1.4	-8.6	-16.6	-7.7
Average Monthly Temperature $_{ALL}$ (°C)	-	-	-	-	2.5	14.1	14.8	11.9	7.1	0.0	-8.4	-15.9	-
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	10.7	9.6	2.4	3.2	2.8	3.7	3.8	3.6	4.1	2.3	4.6	4.4	4.6
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	8.6	2.3	0.2	0.0	0.0	0.0	0.0	0.0	0.5	0.6	2.9	5.3	1.7
Impact of Inversion on Surface Temperature (°C)	9.6	5.9	1.3	1.6	1.4	1.8	1.9	1.8	2.3	1.4	3.7	4.8	3.1

1999	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	30	28	28	28	31	29	15	29	30	28	30	31	
Number of Soundings $_{1600h}$	30	29	30	29	28	29	15	24	29	28	29	28	
Inversion Frequency $_{0400h}$	76.7%	96.4%	60.7%	35.7%	48.4%	58.6%	93.3%	75.9%	46.7%	46.4%	63.3%	80.6%	65.2%
Inversion Frequency $_{1600h}$	70.0%	62.1%	0.0%	0.0%	0.0%	10.3%	33.3%	0.0%	0.0%	14.3%	51.7%	75.0%	26.4%
Average Inversion Depth $_{0400h}$ (m)	333	252	197	157	156	165	162	114	142	155	268	263	197
Average Inversion Depth $_{1600h}$ (m)	455	248	-	-	-	59	84	-	-	188	290	289	230
Average Inversion Strength $_{0400h}$ (°C)	7.9	5.7	2.6	3.1	2.1	4.3	3.0	3.2	1.6	1.4	3.9	3.6	3.5
Average Inversion Strength $_{1600h}$ (°C)	7.5	6.2	-	-	-	0.4	2	-	-	0.7	2.5	3.6	3.2
Average Magnitude $_{0400h}$ (°C)	9.0	7.2	4.6	4.3	3.1	5.9	4.5	4.2	2.6	2.6	4.9	5.1	4.8
Average Magnitude $_{1600h}$ (°C)	9.5	7.3	-	-	-	1.3	2	-	-	2.4	4.1	5.2	4.6
Average Surface Temperature $_{0400h}$ (°C)	-20.8	-17.9	-8.5	-4.9	0.2	6.8	9.6	9.3	3.0	-1.9	-11.6	-10.7	-4.0
Average Surface Temperature $_{1600h}$ (°C)	-21.0	-16.2	-	-	-	6.6	17	-	-	4.4	-8.3	-8.9	-3.7
Average Monthly Temperature $_{ALL}$ (°C)	-20.2	-16.9	-5.7	1.0	5.4	12.9	14.6	13.7	7.6	1.9	-8.4	-9.2	-0.3
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	6.9	7.0	2.6	1.1	2.9	2.6	5.3	2.0	1.2	2.3	3.2	3.9	3.4
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	6.6	4.5	0.0	0.0	0.0	0.1	0.8	0.0	0.0	0.3	2.1	3.9	1.5
Impact of Inversion on Surface Temperature (°C)	6.8	5.7	1.3	0.5	1.4	1.4	3.0	1.0	0.6	1.3	2.7	3.9	2.5

2000	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	30	26	30	30	31	30	31	30	30	31	30	29	
Number of Soundings $_{1600h}$	29	28	30	30	31	29	31	30	30	31	30	26	
Inversion Frequency $_{0400h}$	80.0%	88.5%	46.7%	46.7%	71.0%	70.0%	67.7%	56.7%	63.3%	54.8%	80.0%	89.7%	67.9%
Inversion Frequency $_{1600h}$	62.1%	46.4%	0.0%	0.0%	0.0%	3.4%	6.5%	0.0%	13.3%	6.5%	60.0%	96.2%	24.5%
Average Inversion Depth $_{0400h}$ (m)	484	378	168	95	126	168	141	146	164	155	221	256	208
Average Inversion Depth $_{1600h}$ (m)	472	358	-	-	-	97	243	-	207	138	173	364	256
Average Inversion Strength $_{0400h}$ (°C)	7.1	5.0	3.5	2.0	2.6	2.8	1.9	2.6	2.3	1.5	3.2	5.2	3.3
Average Inversion Strength $_{1600h}$ (°C)	6.5	2.7	-	-	-	0.3	1	-	1.7	0.7	2.4	5.2	2.6
Average Magnitude $_{0400h}$ (°C)	9.8	7.1	4.7	3.1	3.9	4.2	2.9	3.8	3.5	2.5	4.5	6.4	4.7
Average Magnitude $_{1600h}$ (°C)	8.5	3.7	-	-	-	1.3	2	-	1.7	2.2	3.2	7.1	3.7
Average Surface Temperature $_{0400h}$ (°C)	-18.8	-10.2	-8.7	-4.5	0.1	6.5	8.0	6.5	2.6	-3.3	-5.8	-13.5	-3.4
Average Surface Temperature $_{1600h}$ (°C)	-19.7	-5.9	-	-	-	13.9	8	-	11.4	0.9	-4.9	-11.6	-1.0
Average Monthly Temperature $_{ALL}$ (°C)	-16.9	-7.4	-3.3	0.8	5.7	12.3	13.4	11.0	6.2	0.6	-5.0	-13.5	0.3
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	7.9	6.3	1.5	1.8	3.0	2.0	2.6	2.0	1.6	2.5	5.1	4.2	3.4
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	5.3	1.7	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	1.9	6.9	1.4
Impact of Inversion on Surface Temperature (°C)	6.6	4.0	0.7	0.9	1.5	1.0	1.4	1.0	0.9	1.3	3.5	5.5	2.4

2001	January	February	March	April	May	June	July	August	September	October	November	December	Average Annua
Number of Soundings $_{0400h}$	30	28	31	30	31	30	31	31	30	31	28	28	
Number of Soundings $_{1600h}$	31	28	30	30	31	30	31	31	30	31	29	30	
Inversion Frequency $_{0400h}$	86.7%	75.0%	74.2%	73.3%	64.5%	76.7%	58.1%	87.1%	76.7%	58.1%	82.1%	89.3%	75.1%
Inversion Frequency $_{1600h}$	80.6%	60.7%	3.3%	0.0%	0.0%	6.7%	0.0%	3.2%	0.0%	9.7%	65.5%	96.7%	27.2%
Average Inversion Depth $_{0400h}$ (m)	152	412	134	144	104	136	116	157	126	129	200	326	178
Average Inversion Depth $_{1600h}$ (m)	178	361	95	-	-	114	-	59	-	157	200	283	181
Average Inversion Strength $_{0400h}$ (°C)	2.8	6.8	2.8	1.6	1.7	2.3	1.4	2.5	2.2	2.0	2.9	6.0	2.9
Average Inversion Strength $_{1600h}$ (°C)	1.7	4.4	1.0	-	-	0.9	-	2	-	1.3	3.2	4.7	2.4
Average Magnitude $_{0400h}$ (°C)	3.7	8.9	3.8	2.8	2.6	3.2	2.3	3.8	3.2	3.0	3.8	7.4	4.0
Average Magnitude $_{1600h}$ (°C)	2.4	6.3	1.2	-	-	0.7	-	2	-	0.6	3.8	5.5	2.8
Average Surface Temperature $_{0400h}$ (°C)	-5.9	-15.6	-10.6	-3.1	0.4	7.1	9.5	8.8	3.7	-3.1	-8.9	-17.5	-2.9
Average Surface Temperature $_{1600h}$ (°C)	-5.2	-9.1	3.8	-	-	19.8	-	11	-	6.0	-9.4	-16.3	0.1
Average Monthly Temperature $_{ALL}$ (°C)	-5.3	-12.9	-6.7	1.1	5.4	12.4	13.6	13.5	7.7	-0.5	-9.3	-17.3	0.1
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	3.2	6.7	2.1	1.9	2.0	1.8	2.2	2.8	2.3	2.2	6.1	3.6	3.1
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	1.9	3.8	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	2.5	5.3	1.1
Impact of Inversion on Surface Temperature (°C)	2.6	5.3	1.1	0.9	1.0	0.9	1.1	1.4	1.1	1.1	4.3	4.4	2.1

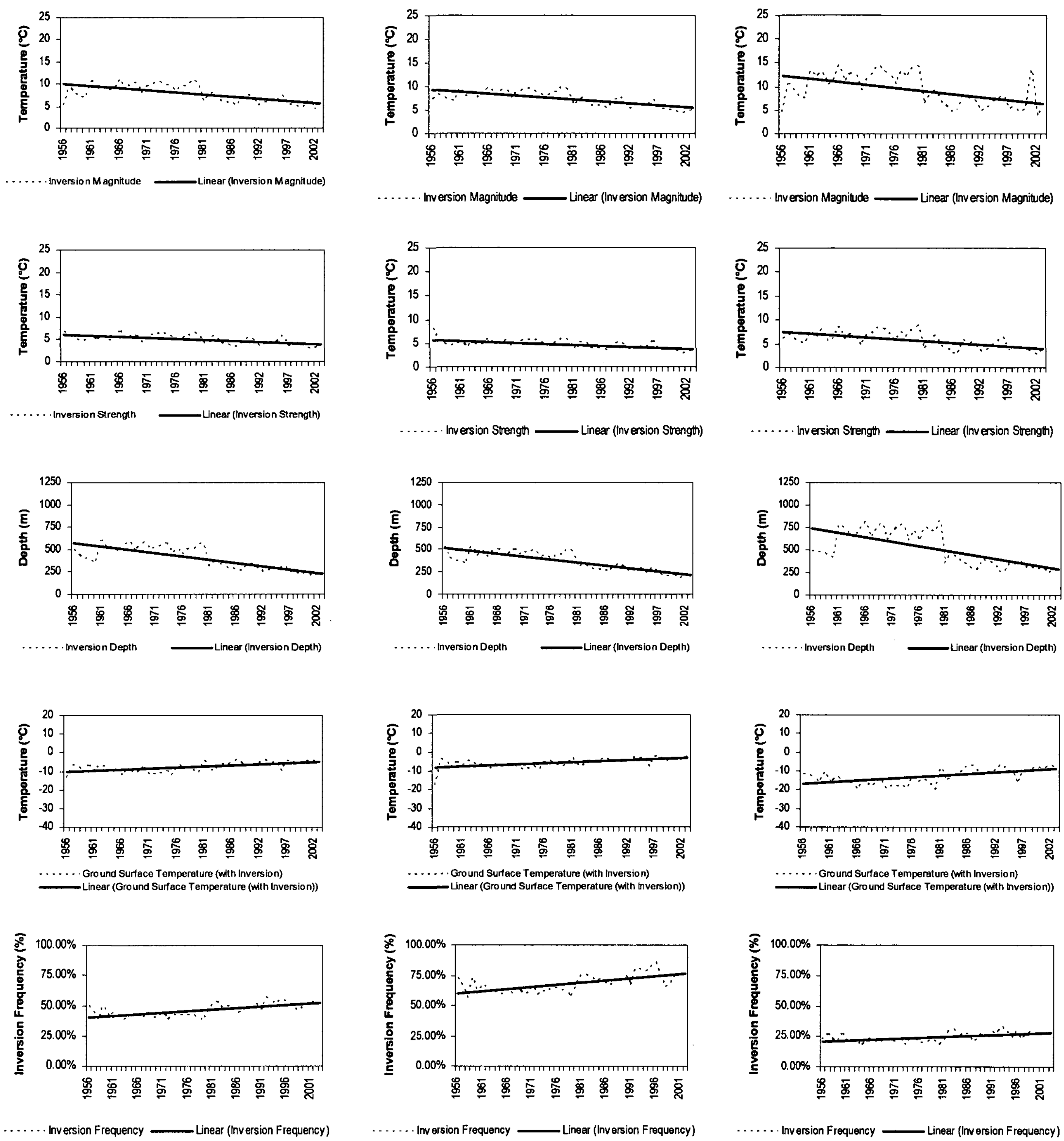
2002	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	31	28	31	28	29	29	31	31	30	31	29	31	
Number of Soundings $_{1600h}$	31	28	31	29	28	30	31	31	30	31	30	30	
Inversion Frequency $_{0400h}$	83.9%	82.1%	67.7%	92.9%	82.8%	62.1%	67.7%	61.3%	73.3%	58.1%	82.8%	87.1%	75.1%
Inversion Frequency $_{1600h}$	77.4%	60.7%	0.0%	6.9%	7.1%	0.0%	3.2%	0.0%	0.0%	19.4%	60.0%	86.7%	26.8%
Average Inversion Depth $_{0400h}$ (m)	214	278	222	154	175	133	130	143	177	238	300	379	212
Average Inversion Depth $_{1600h}$ (m)	193	237	-	19	44	-	38	-	-	333	264	415	193
Average Inversion Strength $_{0400h}$ (°C)	3.7	4.7	5.6	3.2	2.8	2.9	2.1	2.0	2.7	2.0	2.6	5.0	3.3
Average Inversion Strength $_{1600h}$ (°C)	3.8	2.5	-	1	1	-	4	-	-	1.9	1.4	4.3	2.4
Average Magnitude $_{0400h}$ (°C)	4.7	6.6	7.1	4.3	4.3	4.1	3.4	3.0	4.2	3.2	4.5	7.3	4.7
Average Magnitude $_{1600h}$ (°C)	4.3	3.5	-	1	1	-	4	-	-	4.1	2.7	6.5	3.3
Average Surface Temperature $_{0400h}$ (°C)	-11.2	-14.8	-19.5	-8.3	0.8	5.7	7.9	7.5	2.8	0.4	-2.6	-9.7	-3.4
Average Surface Temperature $_{1600h}$ (°C)	-11.5	-10.3	-	4	-1	-	15	-	-	4.5	-0.6	-8.8	-1.1
Average Monthly Temperature $_{ALL}$ (°C)	-12.2	-11.5	-11.7	-3.8	6.3	12.1	13.8	12.1	7.5	3.7	-1.4	-9.3	0.5
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	4.0	5.4	2.9	4.0	3.4	2.1	2.0	2.6	2.4	2.6	6.1	4.1	3.5
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	3.4	2.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.8	1.6	5.7	1.1
Impact of Inversion on Surface Temperature (°C)	3.7	3.8	1.4	2.0	1.7	1.0	1.1	1.3	1.2	1.7	3.8	4.9	2.3

2003	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Number of Soundings $_{0400h}$	30	28	31	30	31	30	31	29	30	31	30	-	
Number of Soundings $_{1600h}$	31	28	31	29	31	29	31	31	30	31	30	29	
Inversion Frequency $_{0400h}$	90.0%	89.3%	71.0%	83.3%	83.9%	66.7%	93.5%	82.8%	63.3%	67.7%	76.7%	-	78.9%
Inversion Frequency $_{1600h}$	83.9%	64.3%	16.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	16.1%	70.0%	79.3%	27.5%
Average Inversion Depth $_{0400h}$ (m)	518	210	173	151	95	121	135	177	135	206	217		194
Average Inversion Depth $_{1600h}$ (m)	519	207	350	-	-	-	-	-	-	184	215	268	291
Average Inversion Strength $_{0400h}$ (°C)	8.6	2.5	3.7	4.3	2.7	2.8	2.3	2.7	2.6	2.9	3.8		3.5
Average Inversion Strength $_{1600h}$ (°C)	7.5	2.5	2.8	-	-	-	-	-	-	2.4	3.2	4.1	3.8
Average Magnitude $_{0400h}$ (°C)	11.0	3.4	5.0	5.7	3.9	3.9	3.2	4.1	3.9	4.6	5.2		4.9
Average Magnitude $_{1600h}$ (°C)	9.9	4.0	4.1	-	-	-	-	-	-	3.0	3.9	5.4	5.0
Average Surface Temperature $_{0400h}$ (°C)	-15.5	-9.2	-11.9	-4.7	0.5	5.5	10.1	7.0	3.8	-0.4	-10.3		-2.3
Average Surface Temperature $_{1600h}$ (°C)	-14.2	-5.2	-6.7	-	-	-	-	-	-	9.7	-8.5	-11.3	-6.0
Average Monthly Temperature $_{ALL}$ (°C)	-13.9	-9.0	-8.9	0.9	6.3	11.6	15.3	12.2	6.0	2.9	-11.2	-11.4	0.1
Average Impact of Inversion on Surface Temperature $_{0400h}$ (°C)	9.9	3.1	3.5	4.7	3.3	2.6	3.0	3.4	2.4	3.1	4.0	-	3.9
Average Impact of Inversion on Surface Temperature $_{1600h}$ (°C)	8.3	2.6	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.7	4.3	1.6
Impact of Inversion on Surface Temperature (°C)	9.1	2.8	2.1	2.4	1.7	1.3	1.5	1.7	1.2	1.8	3.3	2.1	2.6

APPENDIX B: Time series analysis (1956-2003), presented monthly and as an annual average

Time series analysis of the annual average (1956-2003)

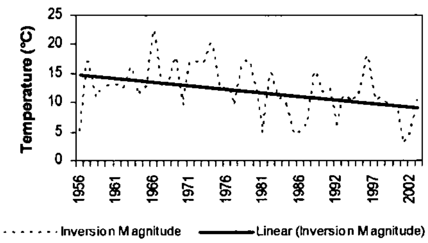
Daily | **0400h** | **1600h**

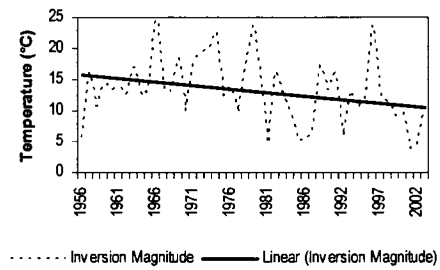


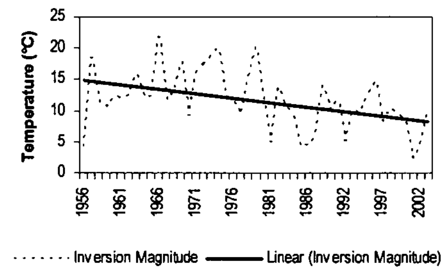
		R Square	Regression Significance F	Coefficients (X variable 1)	Standard Error (X variable 1)	P-value (X variable 1)
Daily	Ground Surface Temperature	0.410	0.000	0.117	0.021	0.000
	Magnitude	0.411	0.000	-0.092	0.016	0.000
	Frequency	0.465	0.000	0.165	0.263	0.000
	Strength	0.415	0.000	-0.048	0.009	0.000
	Depth	0.613	0.000	-7.060	0.836	0.000
AM	Ground Surface Temperature	0.324	0.000	0.108	0.023	0.000
	Magnitude	0.516	0.000	-0.083	0.012	0.000
	Frequency	0.435	0.000	0.106	0.180	0.000
	Strength	0.384	0.000	-0.043	0.008	0.000
	Depth	0.675	0.000	-6.269	0.648	0.000
PM	Ground Surface Temperature	0.345	0.000	0.167	0.034	0.000
	Magnitude	0.282	0.000	-0.128	0.030	0.000
	Frequency	0.326	0.000	0.210	0.450	0.000
	Strength	0.360	0.000	-0.071	0.014	0.000
	Depth	0.473	0.000	-9.634	1.516	0.000

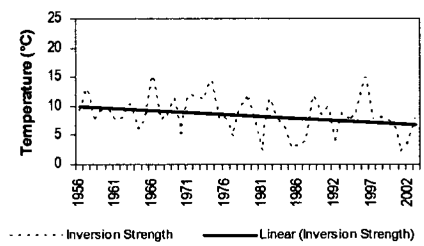
Time series analysis of the January average (1956-2003)

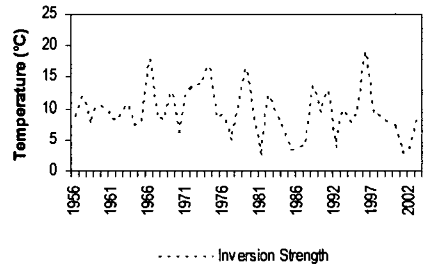
Daily	0400h	1600h

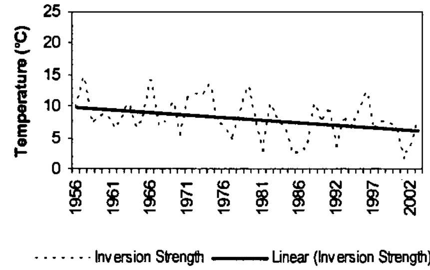


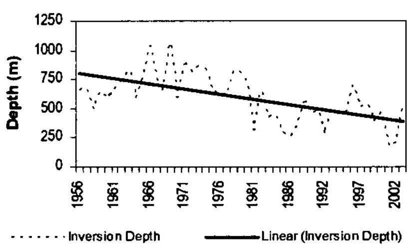


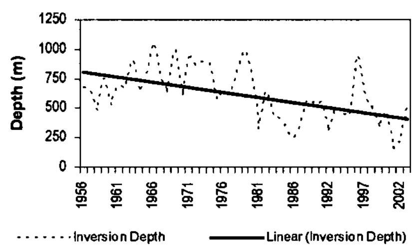


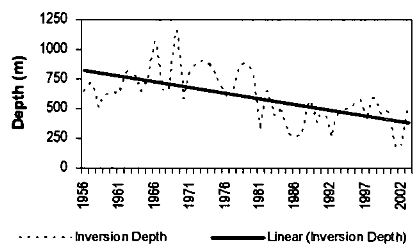


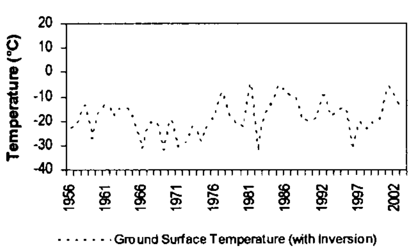


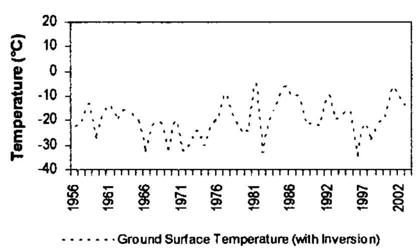


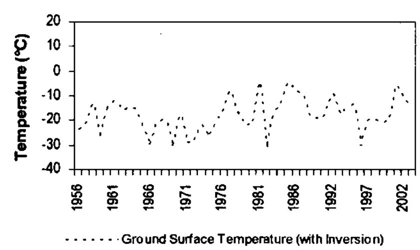


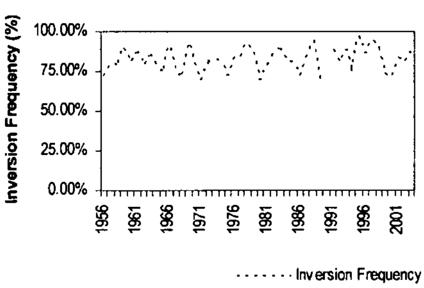


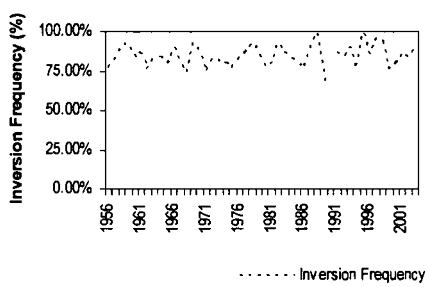


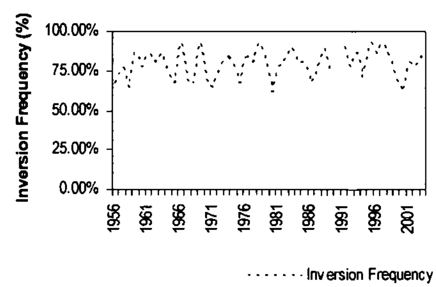








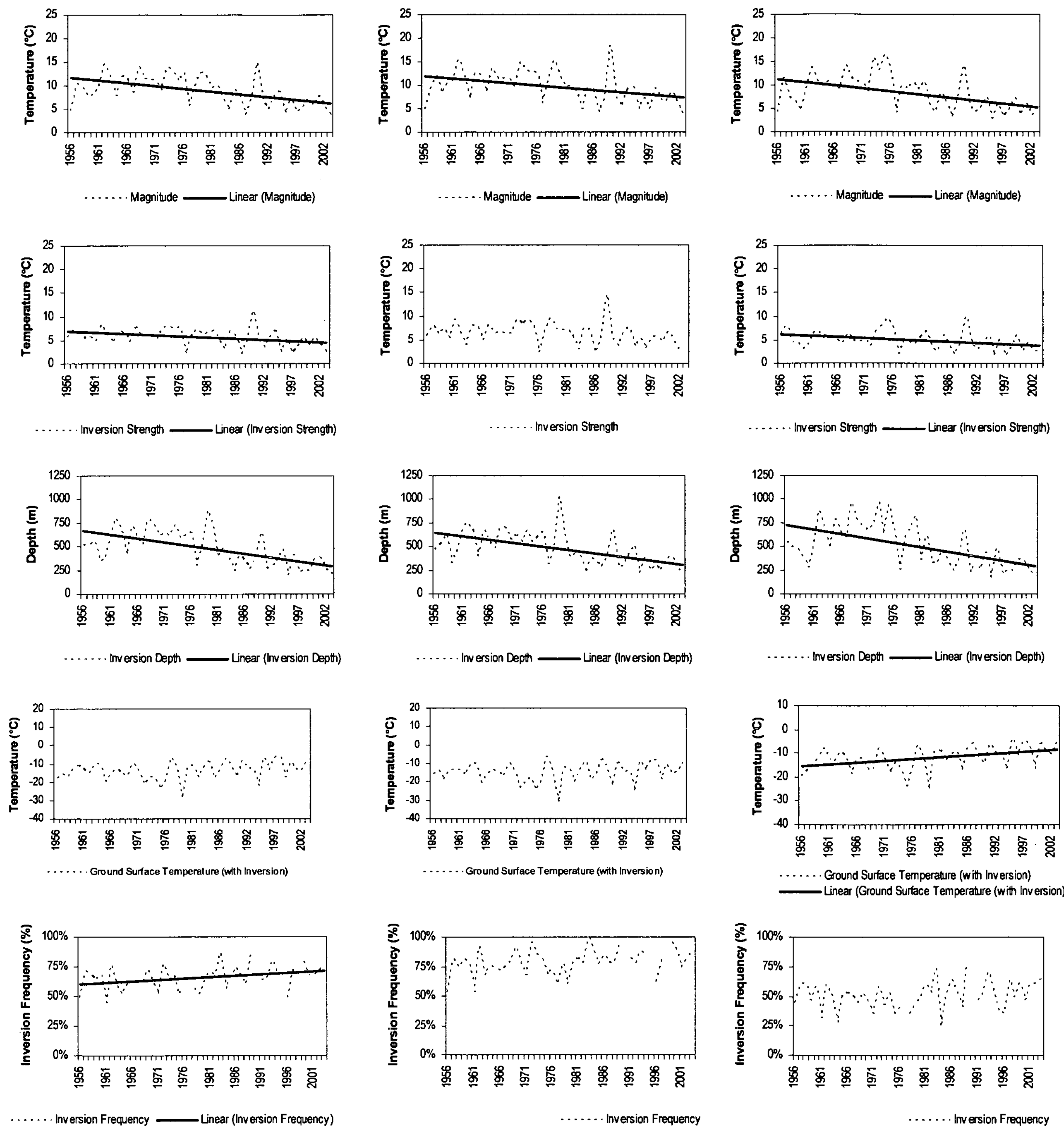




		R Square	Regression Significance F	Coefficients (X variable 1)	Standard Error (X variable 1)	P-value (X variable 1)
Daily	Ground Surface Temperature	0.057	0.105	0.123	0.074	0.105
	Magnitude	0.149	0.007	-0.121	0.043	0.007
	Frequency	0.014	0.430	0.220	0.276	0.430
	Strength	0.087	0.044	-0.067	0.032	0.044
	Depth	0.356	0.000	-8.766	1.756	0.000
AM	Ground Surface Temperature	0.039	0.181	0.108	0.079	0.181
	Magnitude	0.090	0.040	-0.113	0.054	0.040
	Frequency	0.014	0.441	0.230	0.295	0.441
	Strength	0.046	0.148	-0.060	0.041	0.148
	Depth	0.285	0.000	-8.536	2.013	0.000
PM	Ground Surface Temperature	0.077	0.060	0.139	0.072	0.060
	Magnitude	0.180	0.003	-0.140	0.044	0.003
	Frequency	0.011	0.489	0.155	0.222	0.489
	Strength	0.127	0.014	-0.081	0.032	0.014
	Depth	0.355	0.000	-9.299	1.867	0.000

Time series analysis of the February average (1956-2003)

Daily | 0400h | 1600h



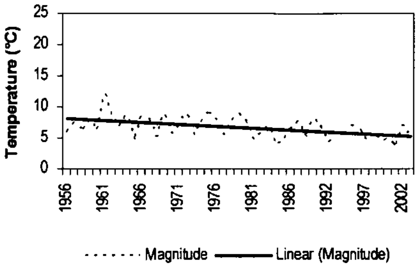
		R Square	Regression Significance F	Coefficients (X variable 1)	Standard Error (X variable 1)	P-value (X variable 1)
Daily	Ground Surface Temperature	0.080	0.054	0.099	0.050	0.054
	Magnitude	0.262	0.000	-0.114	0.029	0.000
	Frequency	0.091	0.050	0.412	0.204	0.050
	Strength	0.134	0.011	-0.049	0.019	0.011
	Depth	0.362	0.000	-7.891	1.561	0.000
AM	Ground Surface Temperature	0.023	0.314	0.056	0.055	0.314
	Magnitude	0.184	0.003	-0.102	0.032	0.003
	Frequency	0.078	0.070	0.376	0.203	0.070
	Strength	0.068	0.076	-0.043	0.024	0.076
	Depth	0.320	0.000	-7.138	1.550	0.000
PM	Ground Surface Temperature	0.181	0.003	0.152	0.048	0.003
	Magnitude	0.235	0.001	-0.127	0.034	0.001
	Frequency	0.046	0.155	0.251	0.173	0.155
	Strength	0.130	0.013	-0.052	0.020	0.013
	Depth	0.319	0.000	-9.156	1.992	0.000

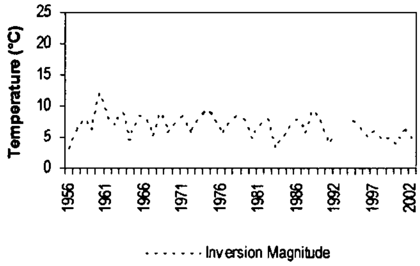
Time series analysis of the March average (1956-2003)

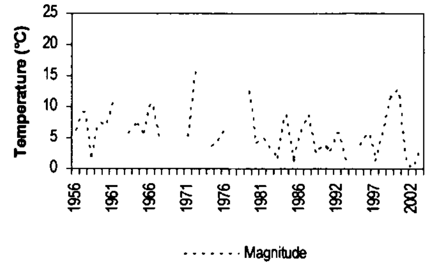
Daily

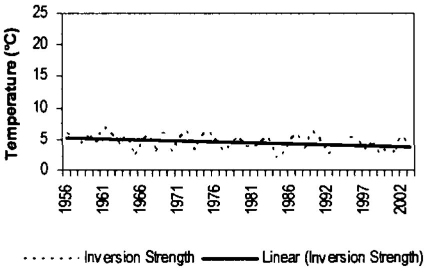
0400h

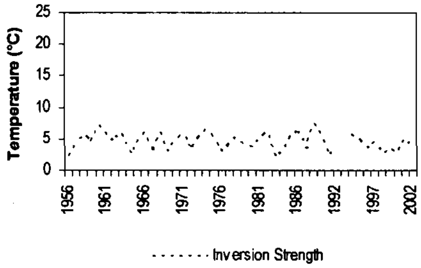
1600h

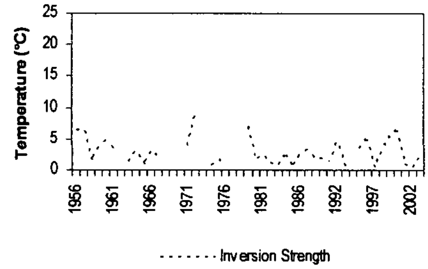


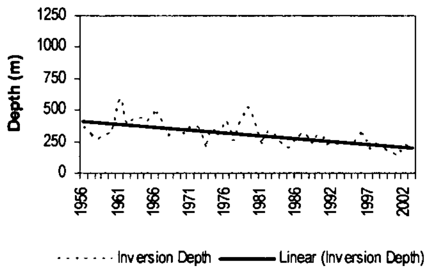


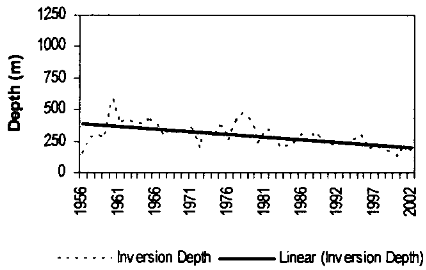


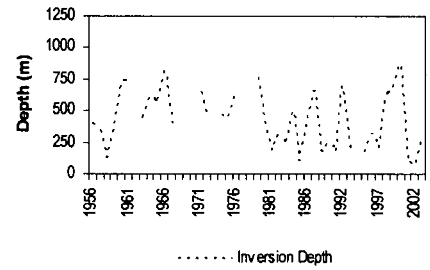


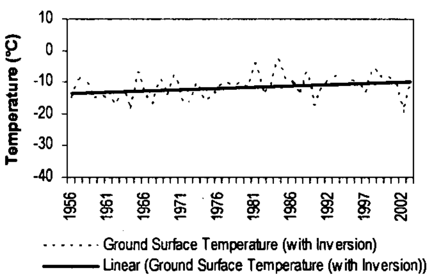


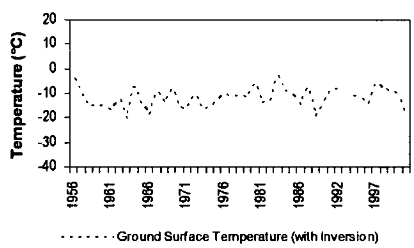


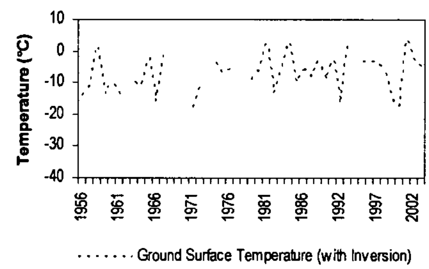


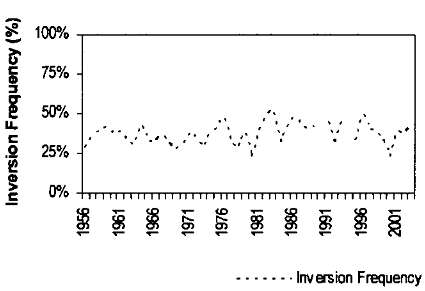


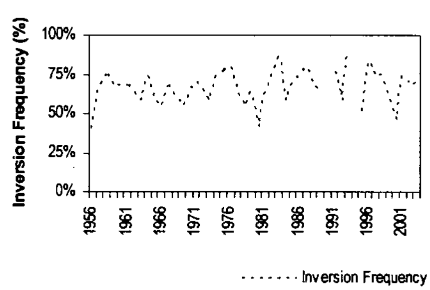


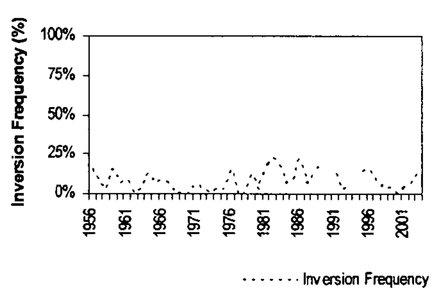








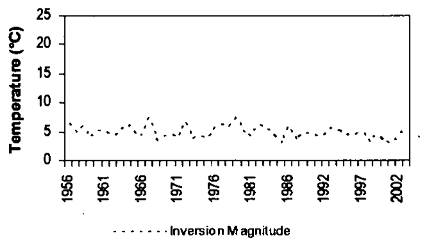


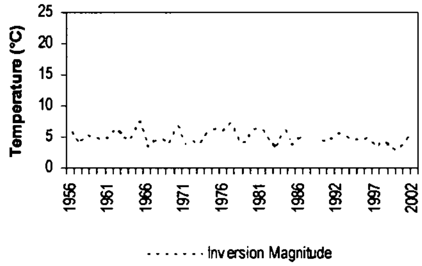


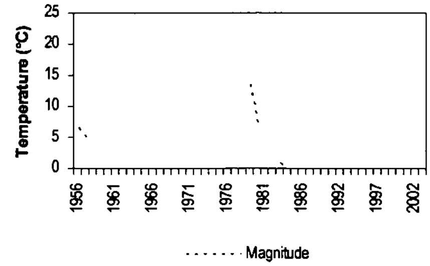
		R Square	Regression Significance F	Coefficients (X variable 1)	Standard Error (X variable 1)	P-value (X variable 1)
Daily	Ground Surface Temperature	0.086	0.047	0.081	0.040	0.047
	Magnitude	0.207	0.001	-0.058	0.017	0.001
	Frequency	0.034	0.226	0.360	0.293	0.226
	Strength	0.104	0.029	-0.030	0.013	0.029
	Depth	0.395	0.000	-4.413	0.823	0.000
AM	Ground Surface Temperature	0.073	0.069	0.088	0.047	0.069
	Magnitude	0.058	0.106	-0.035	0.021	0.106
	Frequency	0.019	0.367	0.187	0.205	0.367
	Strength	0.014	0.440	-0.012	0.015	0.440
	Depth	0.178	0.003	-3.039	0.985	0.003
PM	Ground Surface Temperature	-	-	-	-	-
	Magnitude	-	-	-	-	-
	Frequency	0.032	0.238	0.373	0.311	0.238
	Strength	-	-	-	-	-
	Depth	-	-	-	-	-

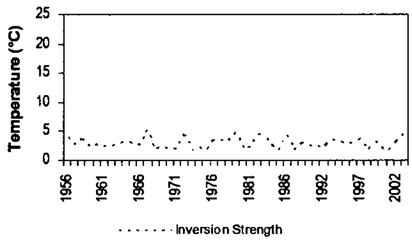
Time series analysis of the April average (1956-2003)

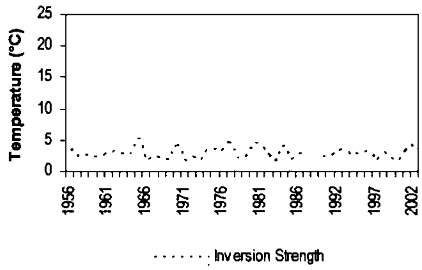
Daily | 0400h | 1600h

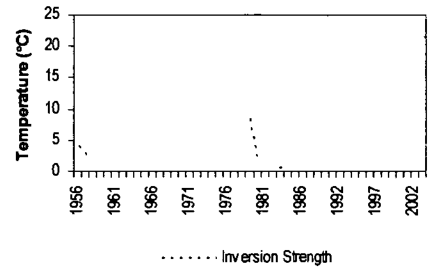


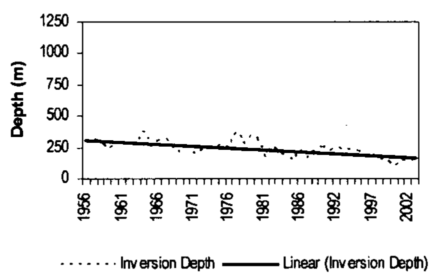


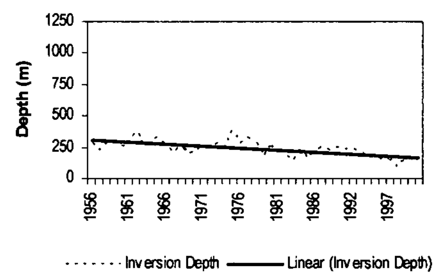


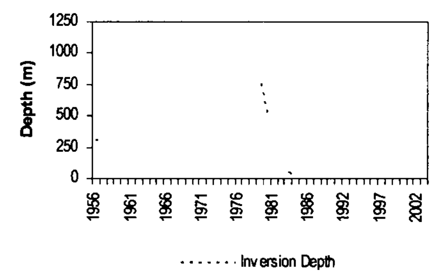


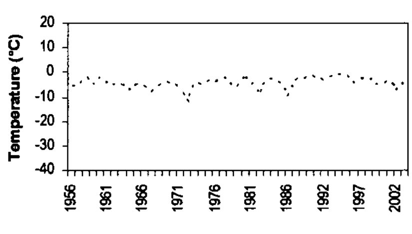


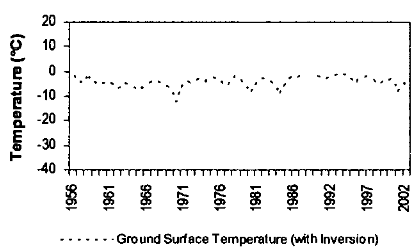


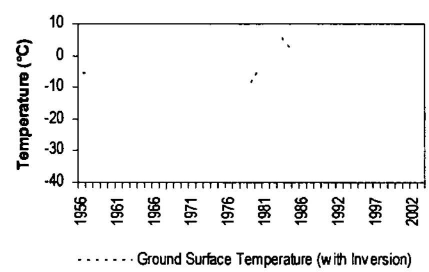


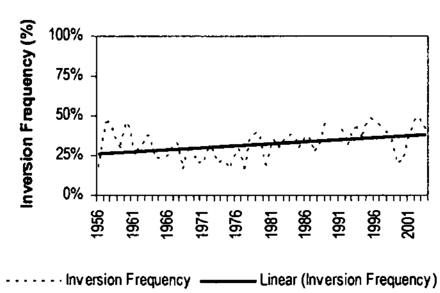


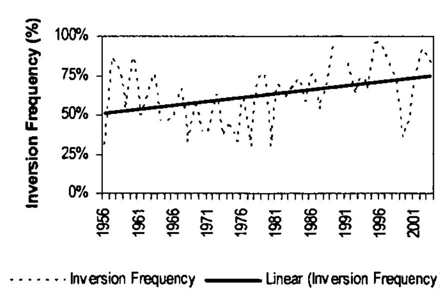


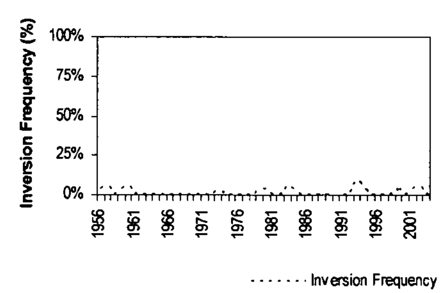








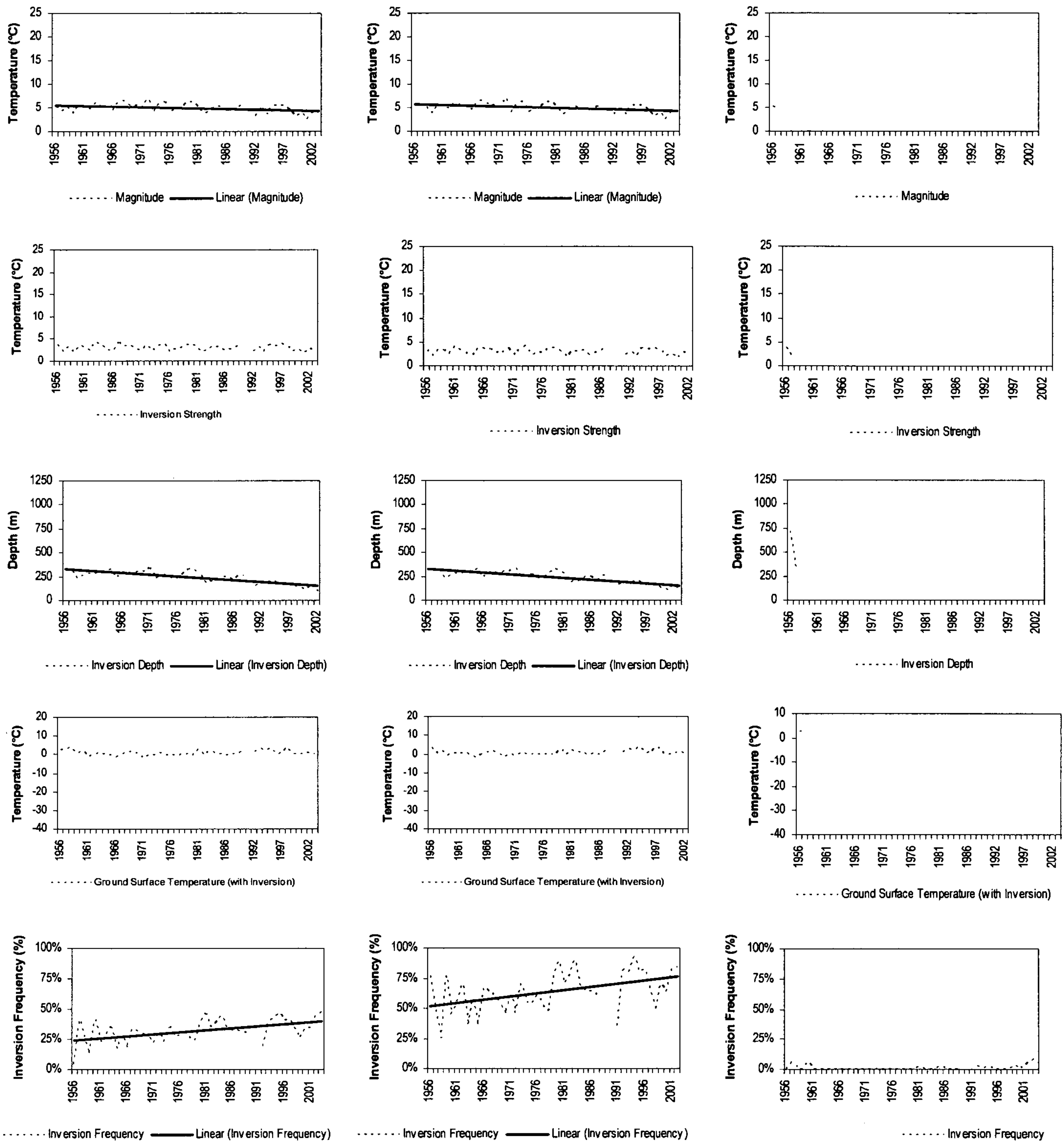




		R Square	Regression Significance F	Coefficients (X variable 1)	Standard Error (X variable 1)	P-value (X variable 1)
Daily	Ground Surface Temperature	0.068	0.077	0.042	0.023	0.077
	Magnitude	0.079	0.056	-0.023	0.012	0.056
	Frequency	0.105	0.028	0.456	0.201	0.028
	Strength	0.002	0.775	-0.003	0.010	0.775
	Depth	0.447	0.000	-3.040	0.504	0.000
AM	Ground Surface Temperature	0.052	0.130	0.040	0.026	0.130
	Magnitude	0.054	0.124	-0.020	0.013	0.124
	Frequency	0.105	0.028	0.237	0.104	0.028
	Strength	0.000	0.933	0.001	0.010	0.933
	Depth	0.424	0.000	-2.984	0.531	0.000
PM	Ground Surface Temperature	-	-	-	-	-
	Magnitude	-	-	-	-	-
	Frequency	0.007	0.568	0.465	0.808	0.568
	Strength	-	-	-	-	-
	Depth	-	-	-	-	-

Time series analysis of the May average (1956-2003)

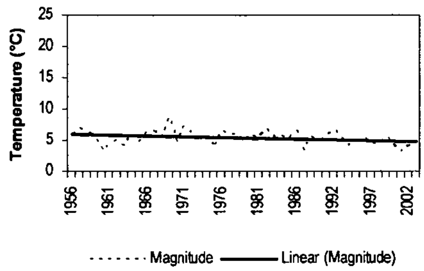
Daily | **0400h** | **1600h**

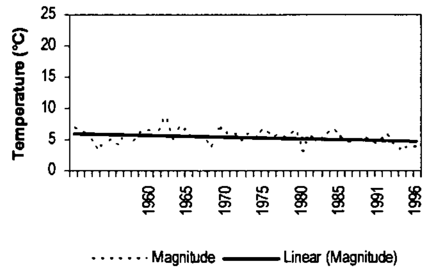


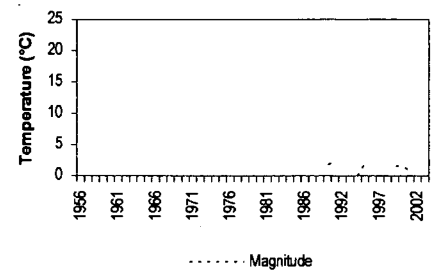
		R Square	Regression Significance F	Coefficients (X variable 1)	Standard Error (X variable 1)	P-value (X variable 1)
Daily	Ground Surface Temperature	0.010	0.508	0.010	0.015	0.508
	Magnitude	0.171	0.004	-0.028	0.009	0.004
	Frequency	0.219	0.001	0.763	0.220	0.001
	Strength	0.026	0.283	-0.008	0.007	0.283
	Depth	0.493	0.000	-4.702	0.719	0.000
AM	Ground Surface Temperature	0.059	0.113	0.023	0.014	0.113
	Magnitude	0.202	0.002	-0.032	0.010	0.002
	Frequency	0.208	0.002	0.392	0.117	0.002
	Strength	0.030	0.264	-0.008	0.007	0.264
	Depth	0.639	0.000	-3.644	0.423	0.000
PM	Ground Surface Temperature	-	-	-	-	-
	Magnitude	-	-	-	-	-
	Frequency	0.066	0.088	0.153	0.876	0.088
	Strength	-	-	-	-	-
	Depth	-	-	-	-	-

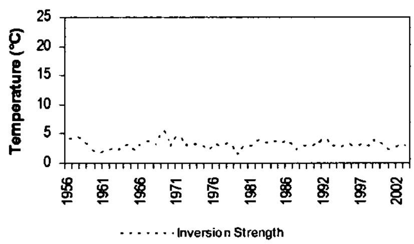
Time series analysis of the June average (1956-2003)

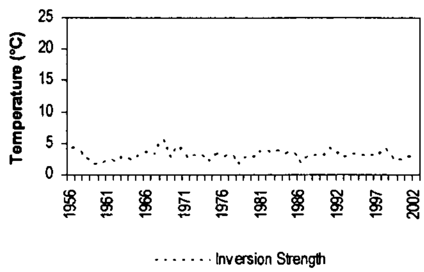
Daily	0400h	1600h

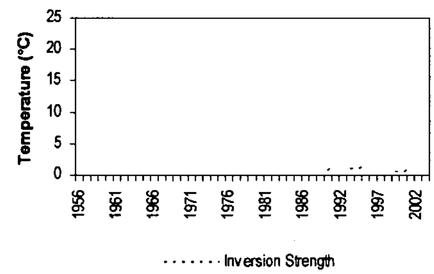


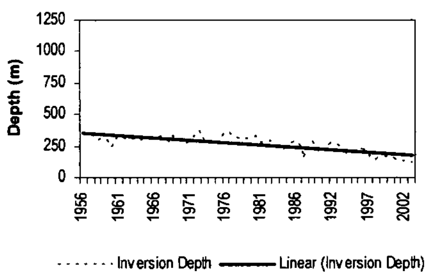


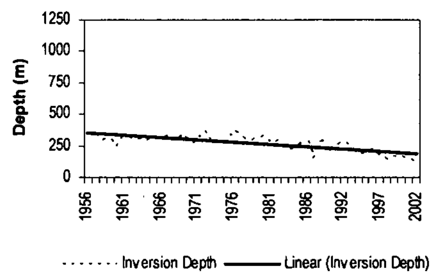


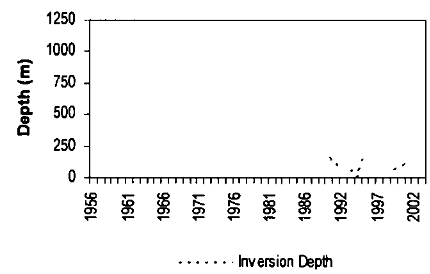


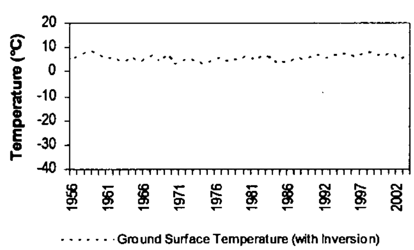


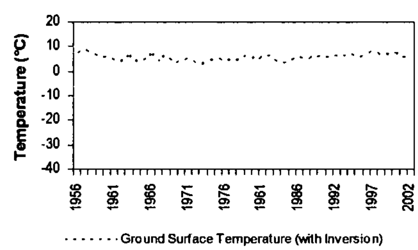


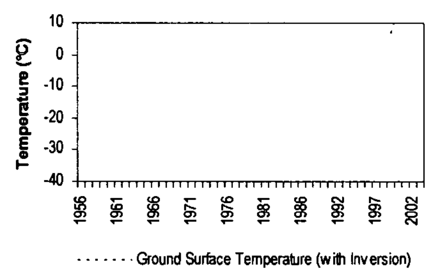


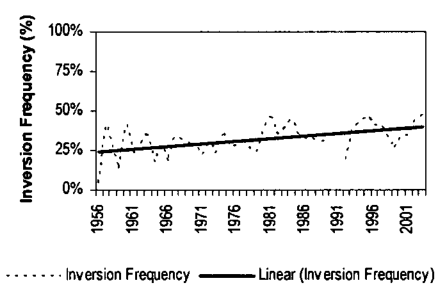


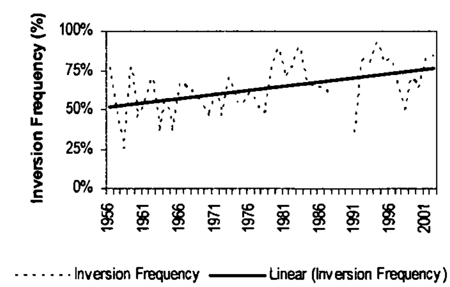


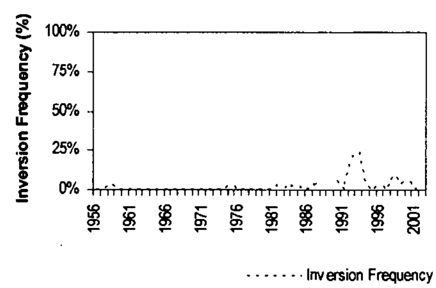








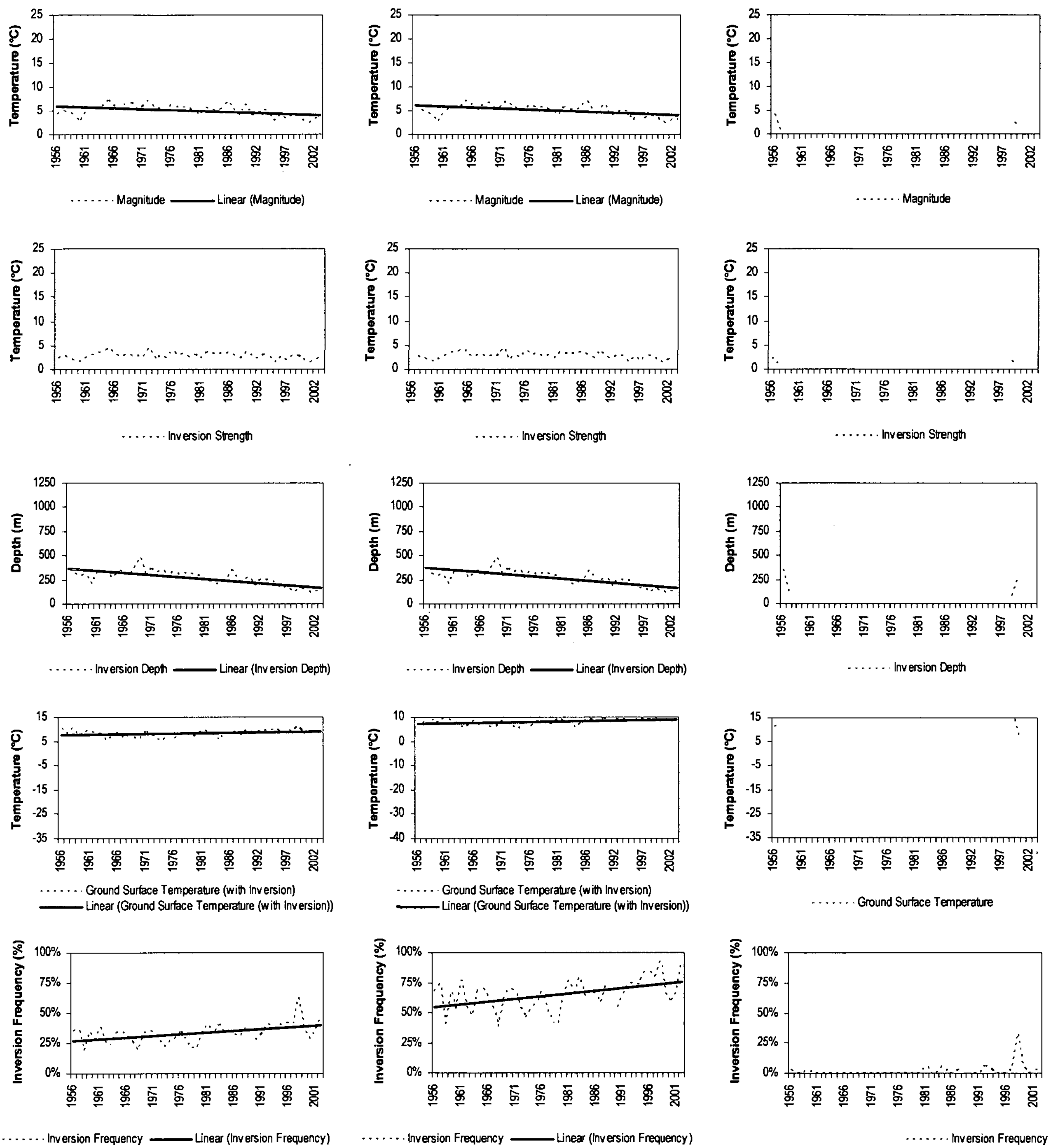




		R Square	Regression Significance F	Coefficients (X variable 1)	Standard Error (X variable 1)	P-value (X variable 1)
Daily	Ground Surface Temperature	0.057	0.107	0.024	0.015	0.107
	Magnitude	0.111	0.022	-0.027	0.011	0.022
	Frequency	0.227	0.001	0.871	0.242	0.001
	Strength	0.002	0.749	-0.003	0.008	0.749
	Depth	0.625	0.000	-3.780	0.436	0.000
AM	Ground Surface Temperature	0.081	0.053	0.030	0.015	0.053
	Magnitude	0.153	0.006	-0.042	0.015	0.006
	Frequency	0.170	0.004	0.446	0.149	0.004
	Strength	0.034	0.217	-0.016	0.013	0.217
	Depth	0.615	0.000	-3.746	0.442	0.000
PM	Ground Surface Temperature	-	-	-	-	-
	Magnitude	-	-	-	-	-
	Frequency	0.159	0.006	0.113	0.390	0.006
	Strength	-	-	-	-	-
	Depth	-	-	-	-	-

Time series analysis of the July average (1956-2003)

Daily 0400h 1600h



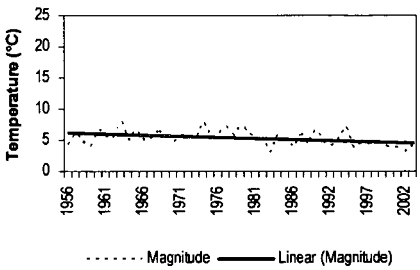
		R Square	Regression Significance F	Coefficients (X variable 1)	Standard Error (X variable 1)	P-value (X variable 1)
Daily	Ground Surface Temperature	0.093	0.037	0.033	0.015	0.037
	Magnitude	0.222	0.001	-0.040	0.011	0.001
	Frequency	0.237	0.001	0.826	0.223	0.001
	Strength	0.059	0.099	-0.012	0.007	0.099
	Depth	0.563	0.000	-4.331	0.568	0.000
AM	Ground Surface Temperature	0.142	0.010	0.038	0.014	0.010
	Magnitude	0.262	0.000	-0.045	0.011	0.000
	Frequency	0.214	0.001	0.479	0.138	0.001
	Strength	0.078	0.060	-0.015	0.008	0.060
	Depth	0.553	0.000	-4.364	0.592	0.000
PM	Ground Surface Temperature	-	-	-	-	-
	Magnitude	-	-	-	-	-
	Frequency	0.112	0.023	0.893	0.378	0.023
	Strength	-	-	-	-	-
	Depth	-	-	-	-	-

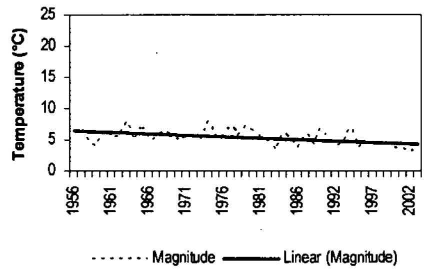
Time series analysis of the August average (1956-2003)

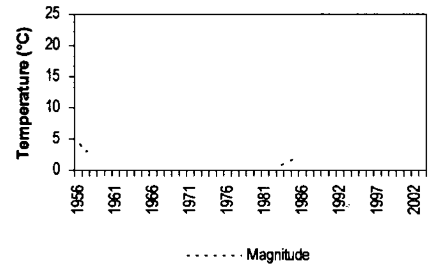
Daily

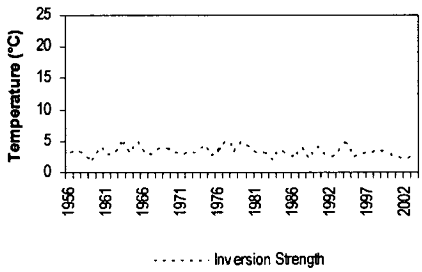
0400h

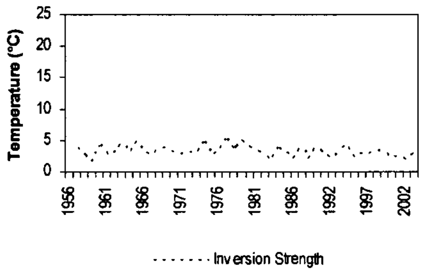
1600h

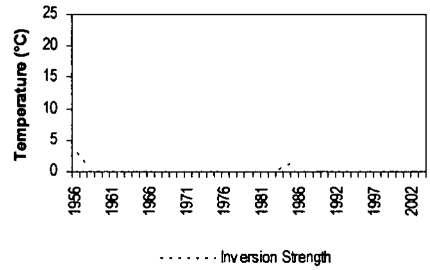


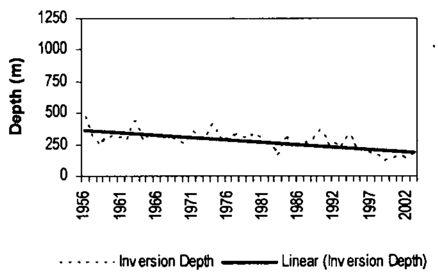


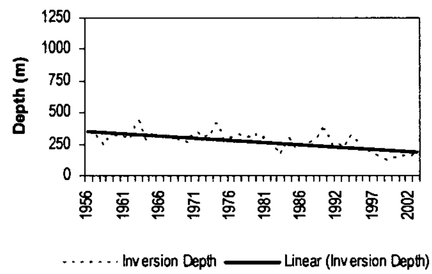


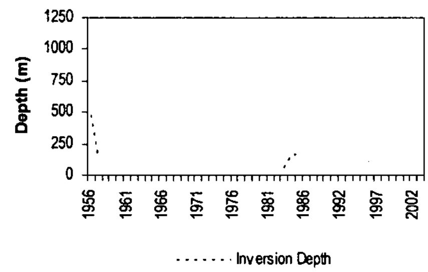


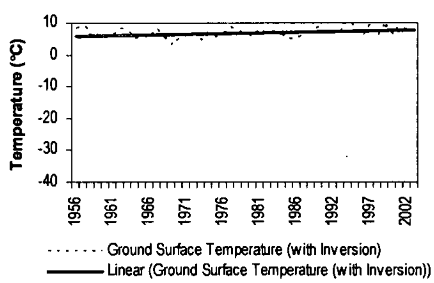


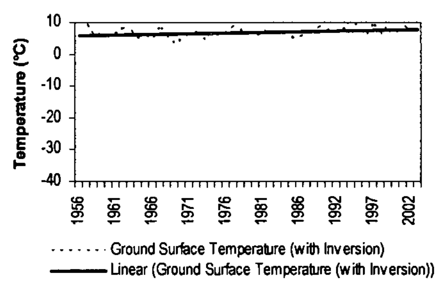


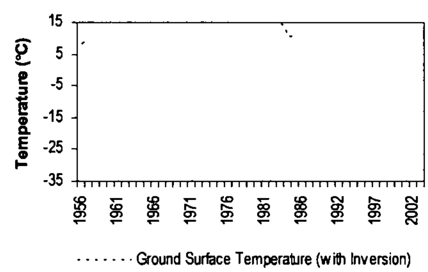


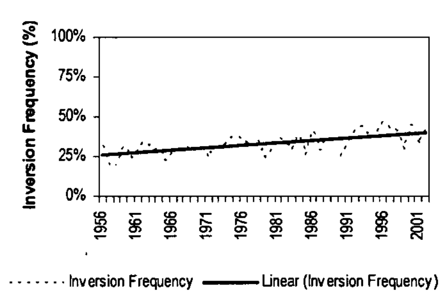


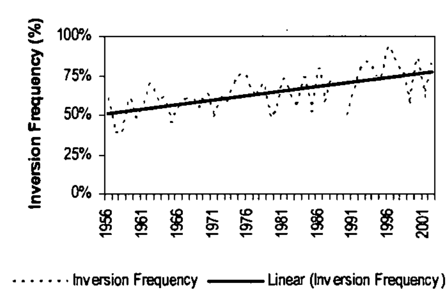


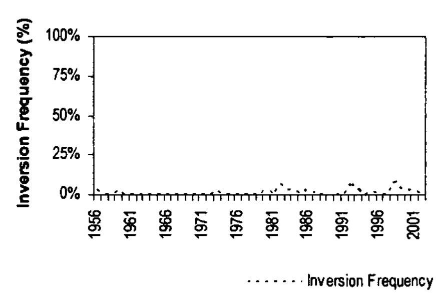








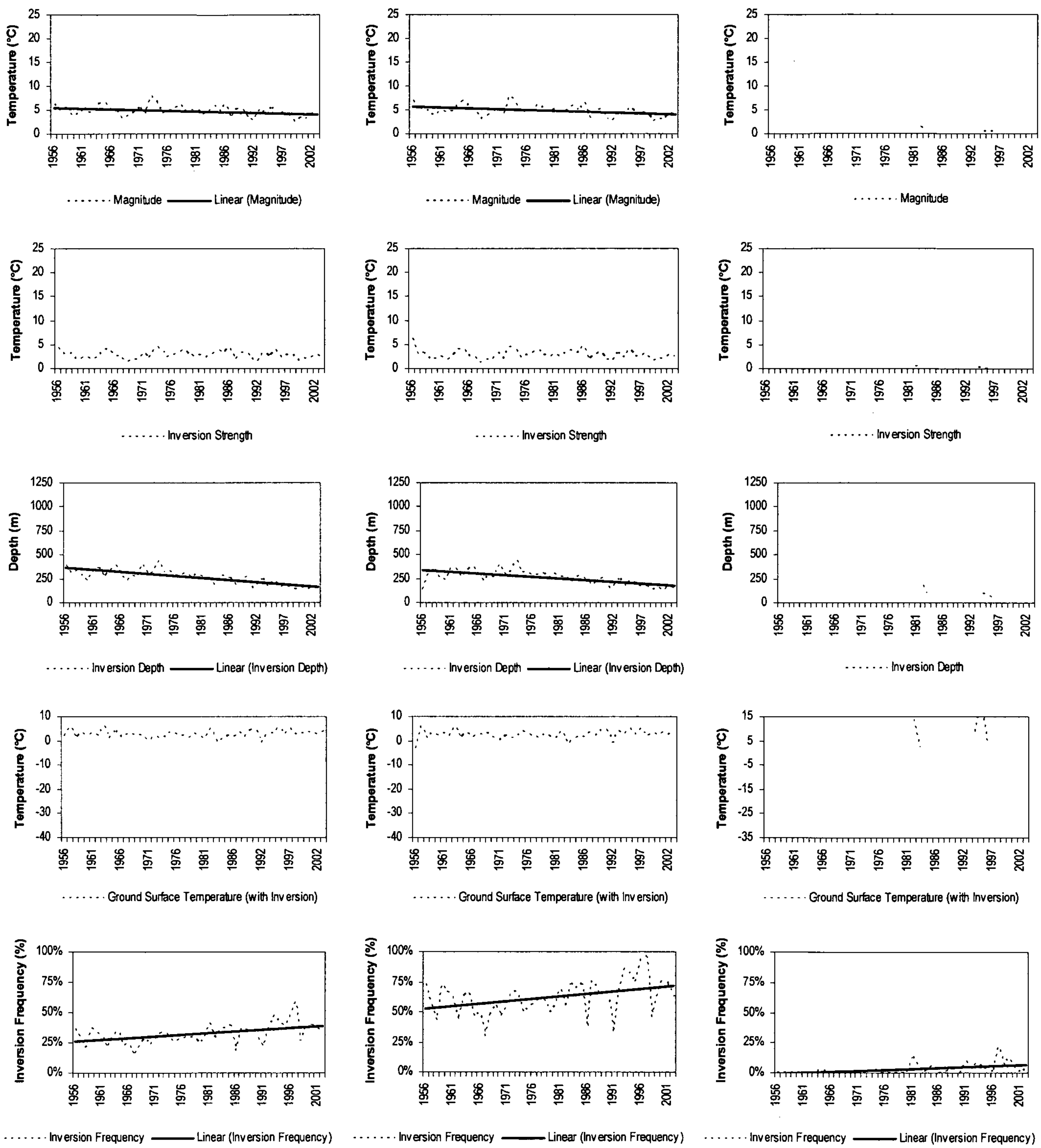




		R Square	Regression Significance F	Coefficients (X variable 1)	Standard Error (X variable 1)	P-value (X variable 1)
Daily	Ground Surface Temperature	0.101	0.029	0.034	0.015	0.029
	Magnitude	0.160	0.005	-0.035	0.012	0.005
	Frequency	0.398	0.000	0.127	0.236	0.000
	Strength	0.045	0.151	-0.012	0.009	0.151
	Depth	0.468	0.000	-3.770	0.599	0.000
AM	Ground Surface Temperature	0.127	0.015	0.039	0.015	0.015
	Magnitude	0.219	0.001	-0.043	0.012	0.001
	Frequency	0.364	0.000	0.639	0.127	0.000
	Strength	0.065	0.086	-0.016	0.009	0.086
	Depth	0.453	0.000	-3.547	0.588	0.000
PM	Ground Surface Temperature	-	-	-	-	-
	Magnitude	-	-	-	-	-
	Frequency	0.131	0.013	0.235	0.911	0.013
	Strength	-	-	-	-	-
	Depth	-	-	-	-	-

Time series analysis of the September average (1956-2003)

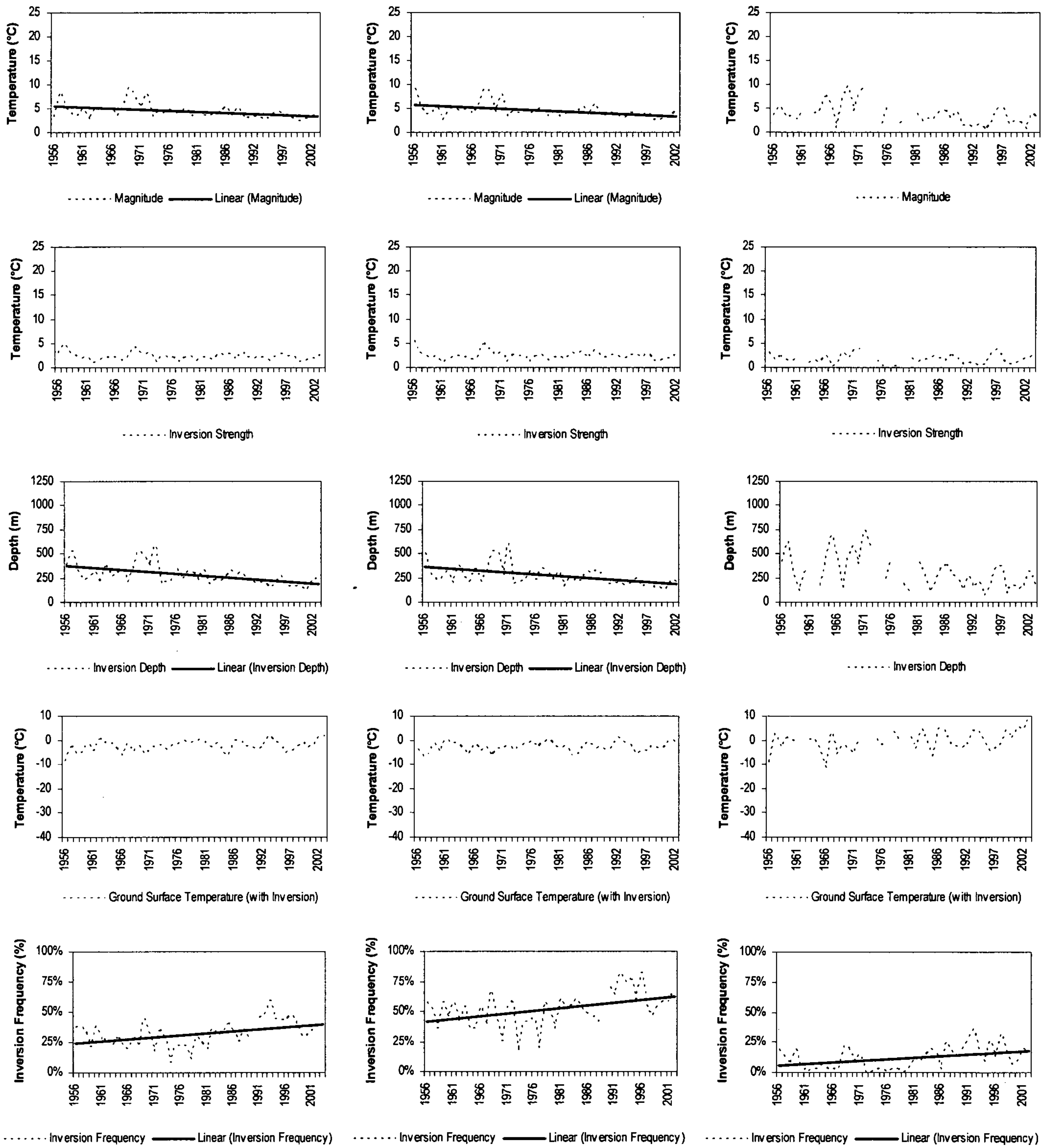
Daily | **0400h** | **1600h**



		R Square	Regression Significance F	Coefficients (X variable 1)	Standard Error (X variable 1)	P-value (X variable 1)
Daily	Ground Surface Temperature	0.011	0.478	0.012	0.016	0.478
	Magnitude	0.151	0.007	-0.032	0.011	0.007
	Frequency	0.231	0.001	0.801	0.221	0.001
	Strength	0.011	0.486	-0.006	0.009	0.486
	Depth	0.591	0.000	-4.209	0.522	0.000
AM	Ground Surface Temperature	0.031	0.237	0.022	0.018	0.237
	Magnitude	0.165	0.005	-0.035	0.012	0.005
	Frequency	0.151	0.008	0.370	0.132	0.008
	Strength	0.022	0.323	-0.010	0.010	0.323
	Depth	0.439	0.000	-3.565	0.601	0.000
PM	Ground Surface Temperature	-	-	-	-	-
	Magnitude	-	-	-	-	-
	Frequency	0.249	0.000	0.148	0.388	0.000
	Strength	-	-	-	-	-
	Depth	-	-	-	-	-

Time series analysis of the October average (1956-2003)

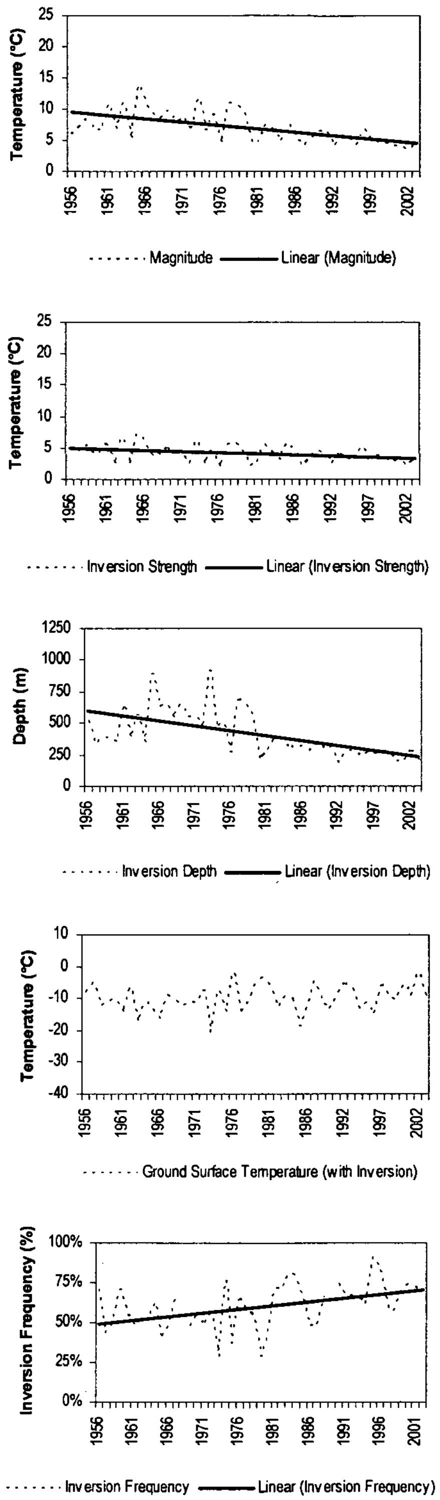
Daily | 0400h | 1600h



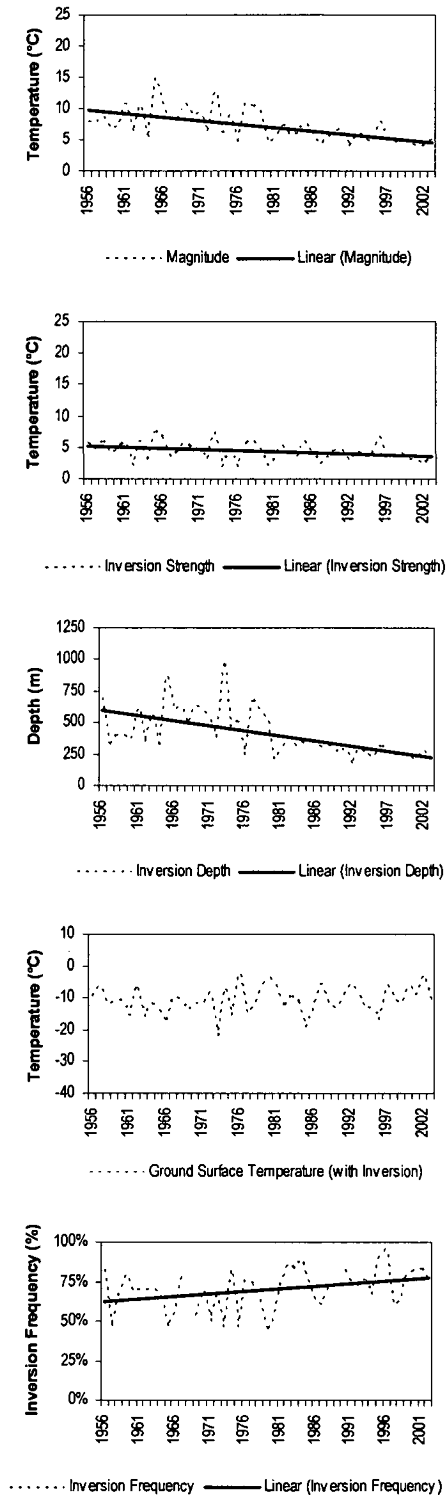
		R Square	Regression Significance F	Coefficients (X variable 1)	Standard Error (X variable 1)	P-value (X variable 1)
Daily	Ground Surface Temperature	0.099	0.031	0.051	0.023	0.031
	Magnitude	0.199	0.002	-0.049	0.015	0.002
	Frequency	0.234	0.001	0.639	0.174	0.001
	Strength	0.051	0.128	-0.013	0.008	0.128
	Depth	0.288	0.000	-4.024	0.943	0.000
AM	Ground Surface Temperature	0.031	0.241	0.026	0.022	0.241
	Magnitude	0.204	0.002	-0.052	0.015	0.002
	Frequency	0.184	0.003	0.407	0.129	0.003
	Strength	0.032	0.235	-0.012	0.010	0.235
	Depth	0.244	0.000	-3.799	1.009	0.000
PM	Ground Surface Temperature	-	-	-	-	-
	Magnitude	-	-	-	-	-
	Frequency	0.170	0.004	0.608	0.202	0.004
	Strength	-	-	-	-	-
	Depth	-	-	-	-	-

Time series analysis of the November average (1956-2003)

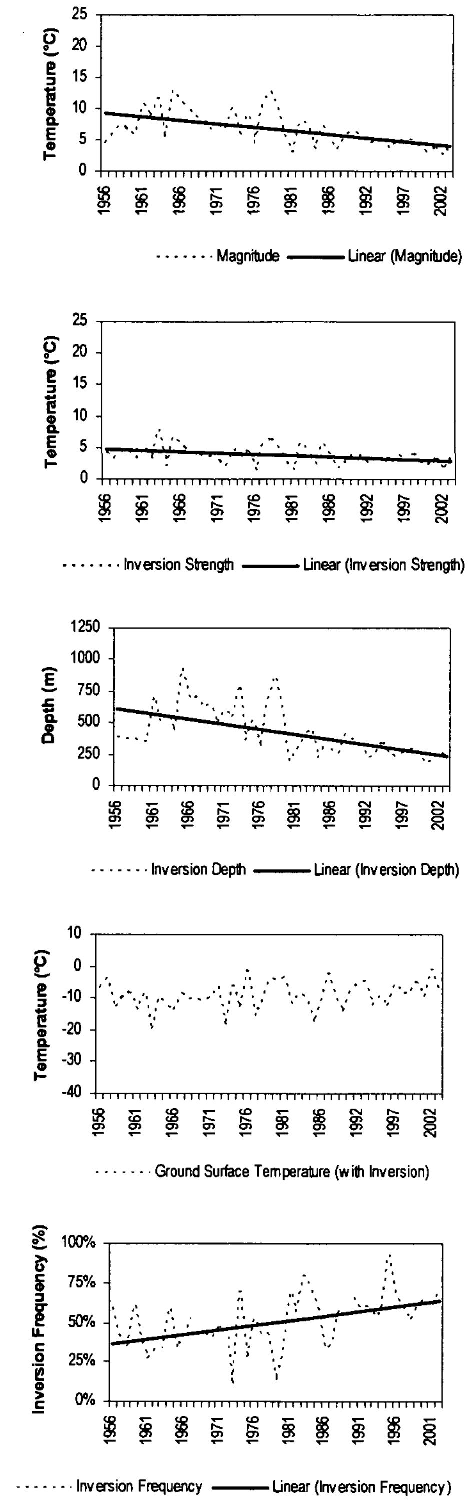
Daily



0400h



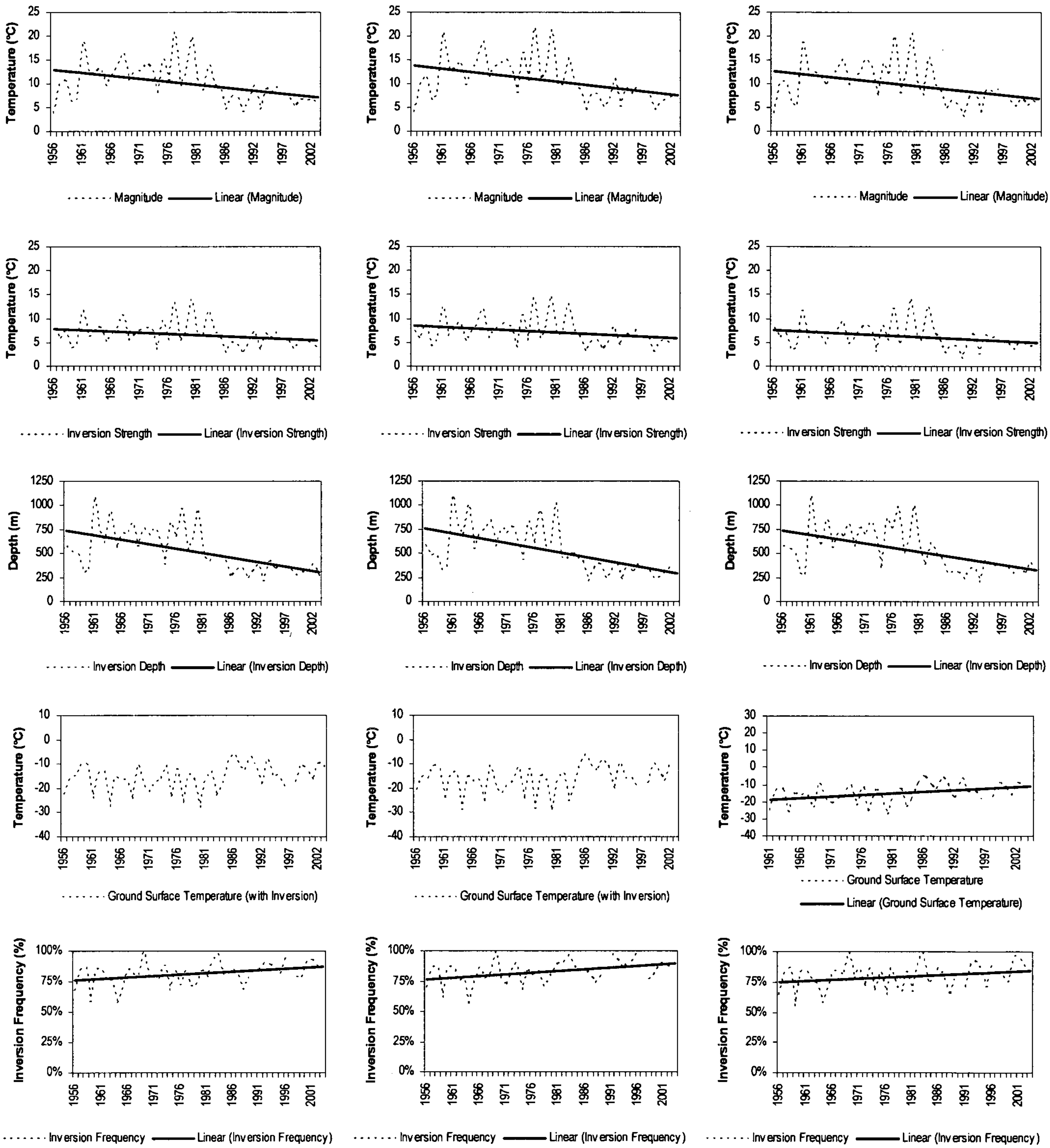
1600h



		R Square	Regression Significance F	Coefficients (X variable 1)	Standard Error (X variable 1)	P-value (X variable 1)
Daily	Ground Surface Temperature	0.043	0.160	0.063	0.044	0.160
	Magnitude	0.351	0.000	-0.107	0.022	0.000
	Frequency	0.198	0.002	0.429	0.132	0.002
	Strength	0.132	0.012	-0.035	0.014	0.012
	Depth	0.368	0.000	-7.792	1.524	0.000
AM	Ground Surface Temperature	0.031	0.239	0.054	0.045	0.239
	Magnitude	0.337	0.000	-0.108	0.023	0.000
	Frequency	0.117	0.021	0.355	0.149	0.021
	Strength	0.107	0.025	-0.035	0.015	0.025
	Depth	0.356	0.000	-7.872	1.579	0.000
PM	Ground Surface Temperature	0.059	0.101	0.076	0.045	0.101
	Magnitude	0.325	0.000	-0.112	0.024	0.000
	Frequency	0.230	0.001	0.390	0.109	0.001
	Strength	0.144	0.008	-0.039	0.014	0.008
	Depth	0.344	0.000	-8.097	1.667	0.000

Time series analysis of the December average (1956-2003)

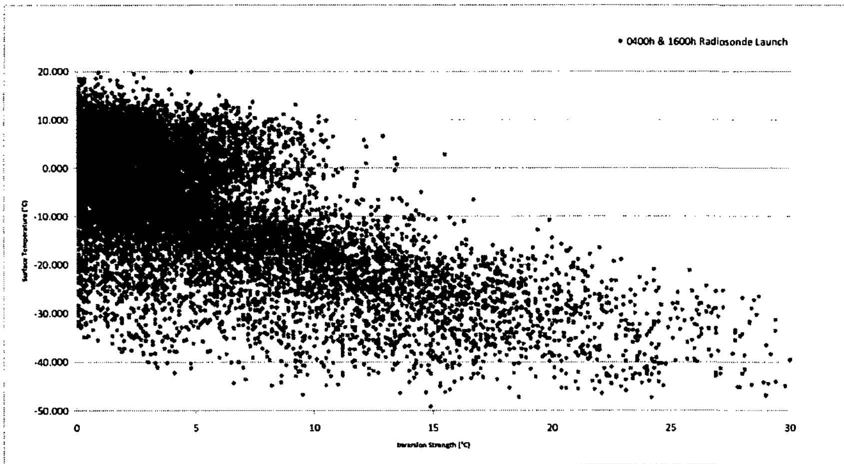
Daily | 0400h | 1600h

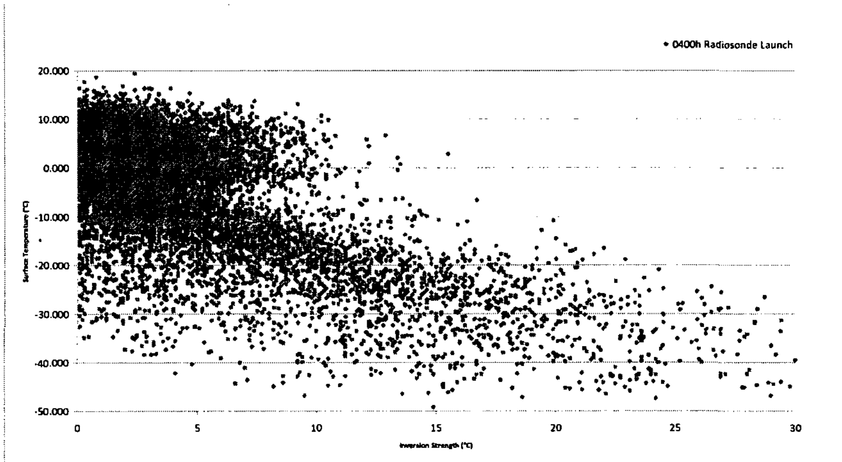


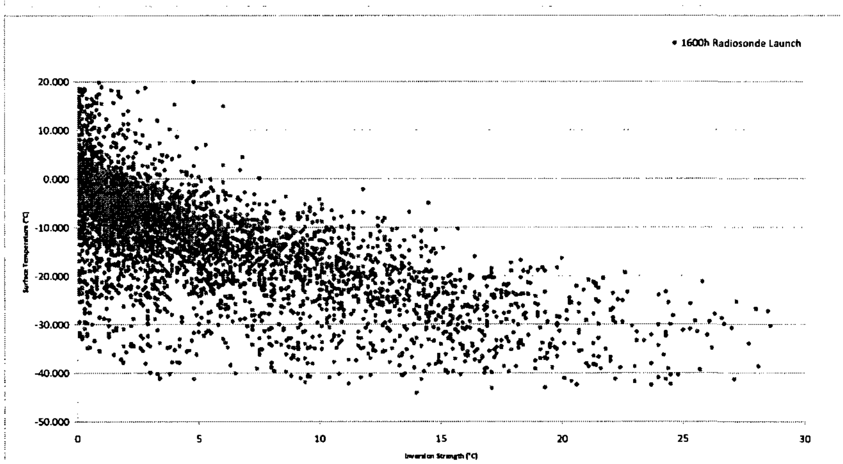
		R Square	Regression Significance F	Coefficients (X variable 1)	Standard Error (X variable 1)	P-value (X variable 1)
Daily	Ground Surface Temperature	0.078	0.060	0.113	0.059	0.060
	Magnitude	0.171	0.004	-0.122	0.041	0.004
	Frequency	0.106	0.031	0.454	0.203	0.031
	Strength	0.086	0.047	-0.055	0.027	0.047
	Depth	0.335	0.000	-9.284	1.973	0.000
AM	Ground Surface Temperature	0.055	0.120	0.102	0.064	0.120
	Magnitude	0.165	0.006	-0.134	0.046	0.006
	Frequency	0.139	0.013	0.507	0.195	0.013
	Strength	0.078	0.062	-0.059	0.031	0.062
	Depth	0.343	0.000	-10.105	2.134	0.000
PM	Ground Surface Temperature	0.100	0.032	0.128	0.058	0.032
	Magnitude	0.155	0.007	-0.119	0.042	0.007
	Frequency	0.070	0.076	0.333	0.183	0.076
	Strength	0.085	0.049	-0.057	0.028	0.049
	Depth	0.289	0.000	-8.820	2.088	0.000

APPENDIX C: Regression analyses of inversion parameters (1956-2003)

Inversion Strength vs. Surface Temperature During an Inversion: 1956-2003

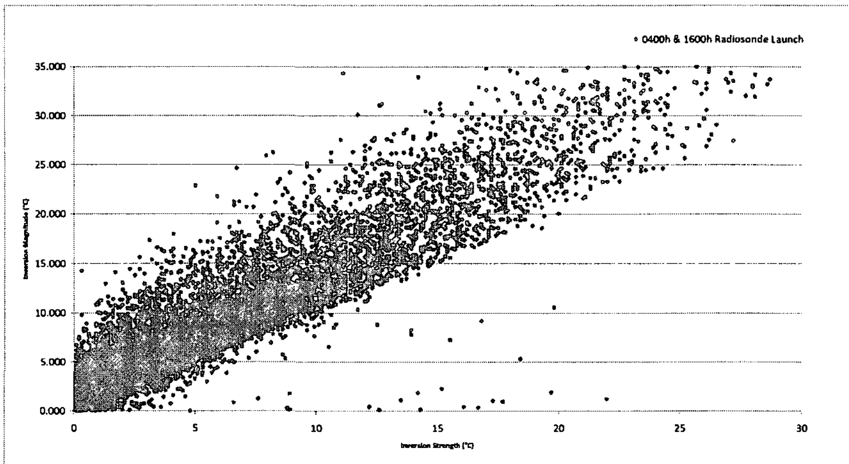


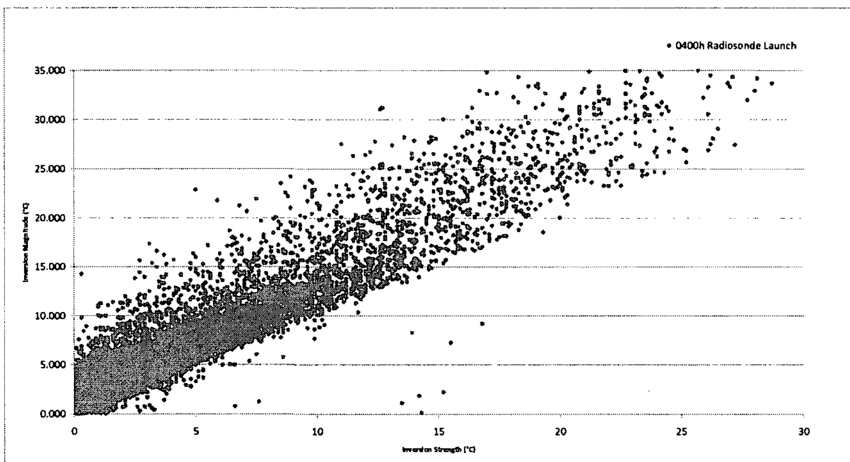


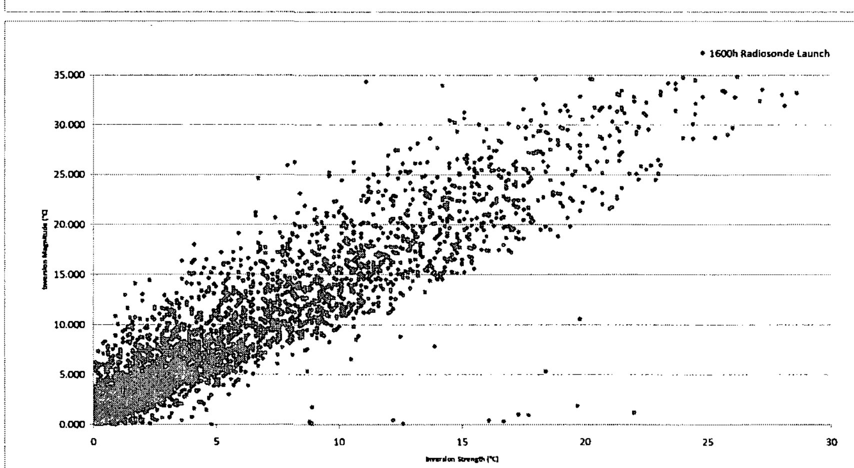


	Daily	0400h	1600h
R Square	0.439341807	0.445134434	0.458910995
Significance F	0	0	0
Coefficients (X Variable 1)	-0.274368889	-0.267243554	-0.3336859
Standard Error (X Variable 1)	0.002408969	0.002835584	0.005676023
P-value	0	0	0

Inversion Strength vs. Inversion Magnitude: 1956-2003

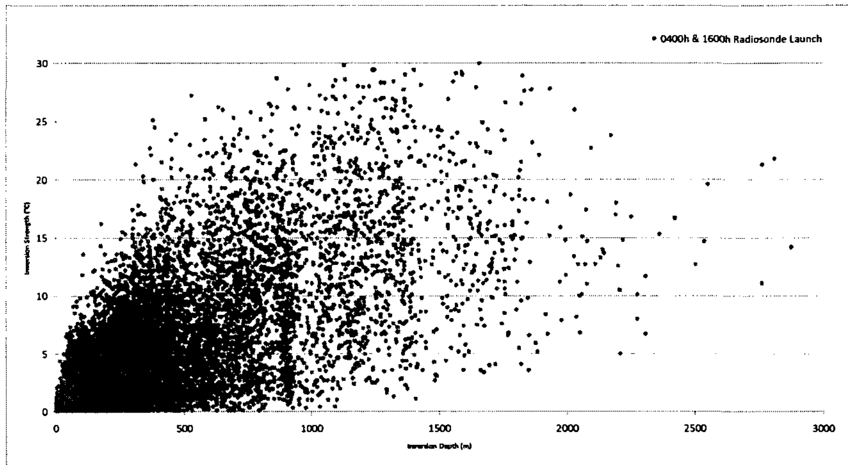


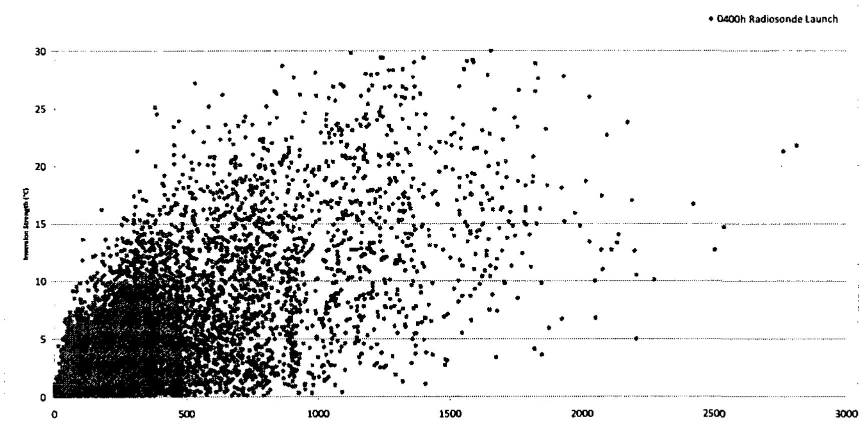


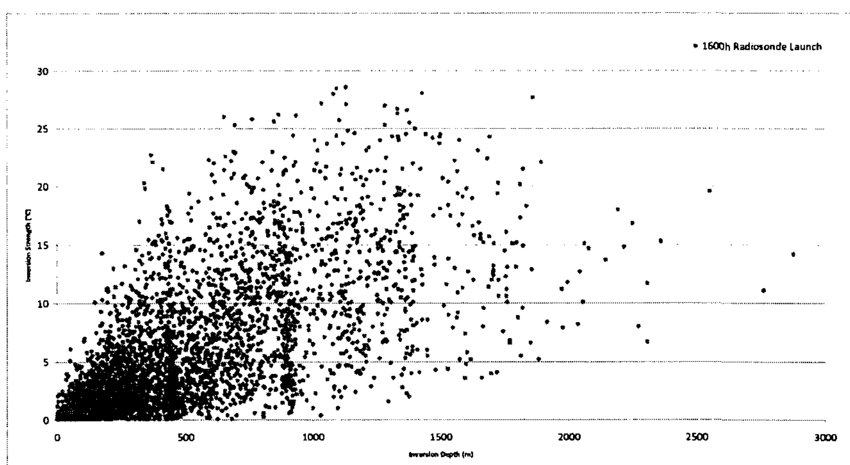


	Daily	0400h	1600h
R Square	0.420026358	0.895097743	0.236712279
Significance F	0	0	4.11E-237
Coefficients (X Variable 1)	0.312793634	0.713354639	0.155817827
Standard Error (X Variable 1)	0.002996294	0.002323909	0.004422401
P-value	0	0	4.11E-237

Inversion Strength vs. Inversion Depth: 1956-2003

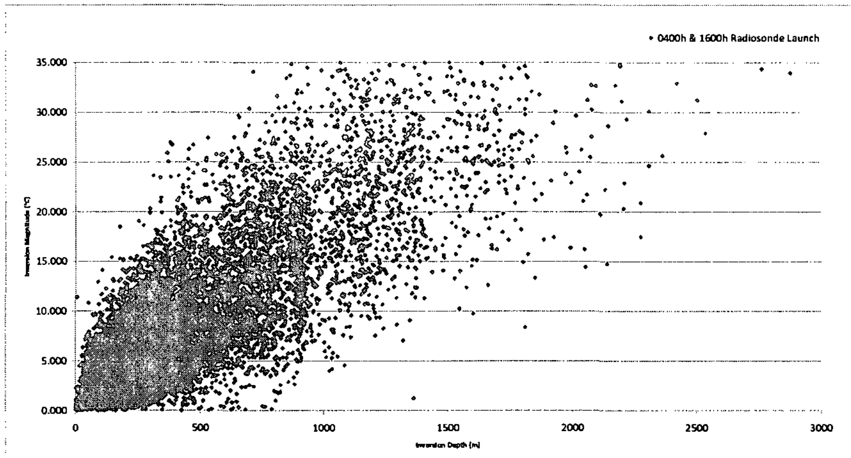


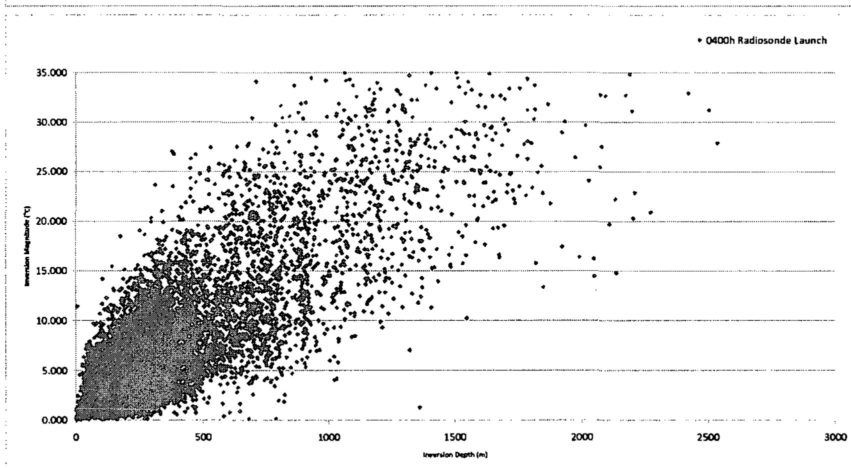


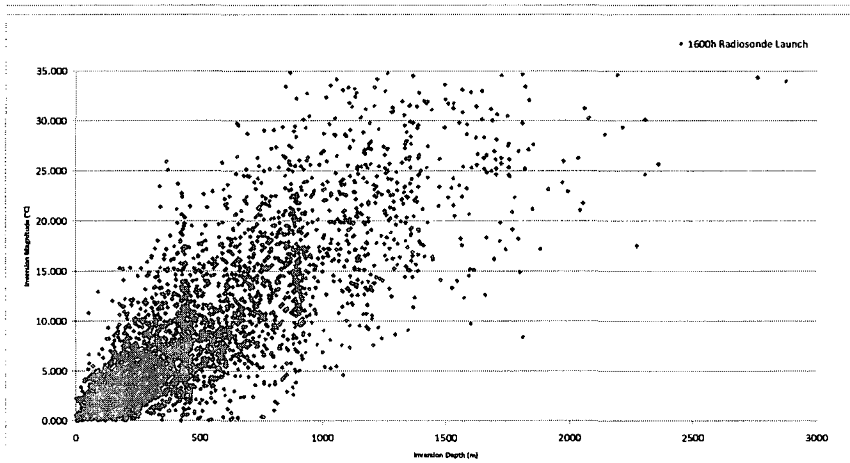


	Daily	0400h	1600h
R Square	0.435070476	0.428570902	0.443911796
Significance F	0	0	0
Coefficients (X Variable 1)	44.48325129	41.69930517	48.22761253
Standard Error (X Variable 1)	0.412024119	0.457702936	0.846516787
P-value	0	0	0

Inversion Magnitude vs. Inversion Depth: 1956-2003

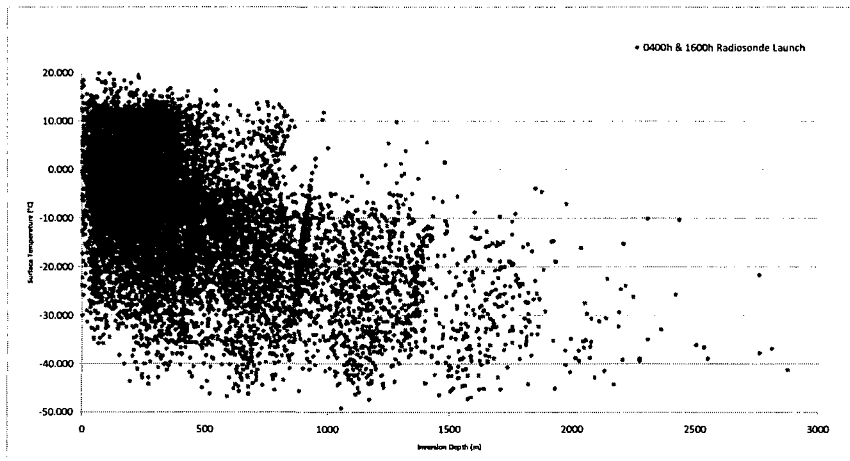


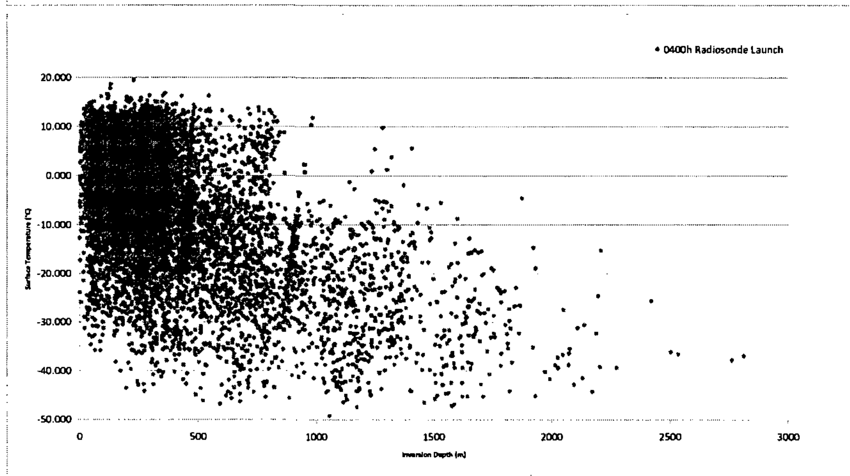


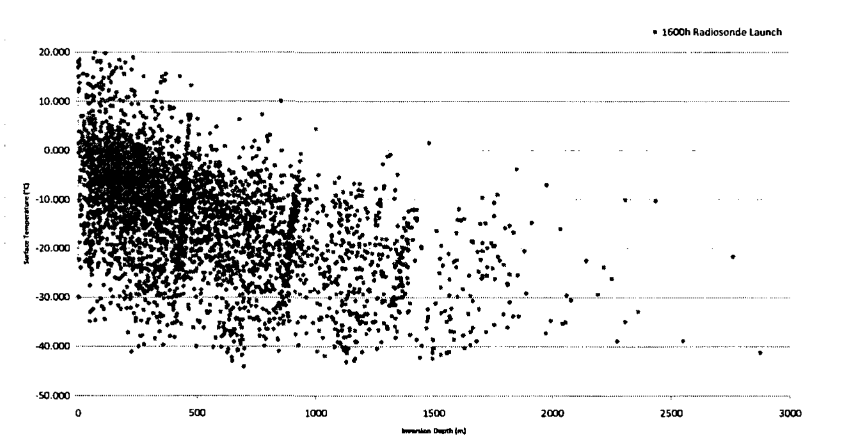


	Daily	0400h	1600h
R Square	0.650698285	0.642334256	0.659016665
Significance F	0	0	0
Coefficients (X Variable 1)	40.13916168	38.54735519	41.55751454
Standard Error (X Variable 1)	0.240660765	0.27425615	0.476778236
P-value	0	0	0

Surface Temperature During an Inversion vs. Inversion Depth: 1956-2003

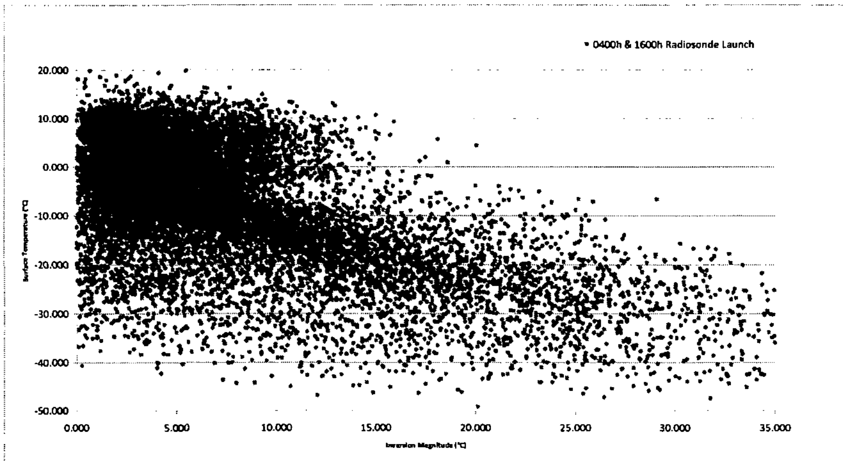


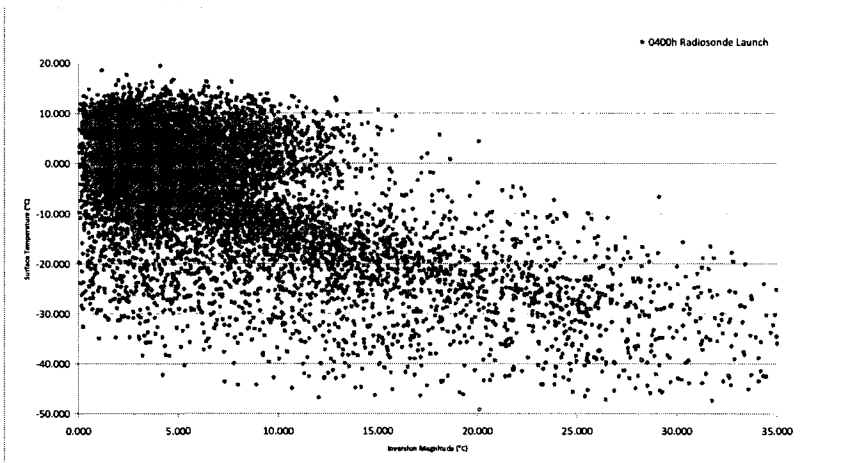


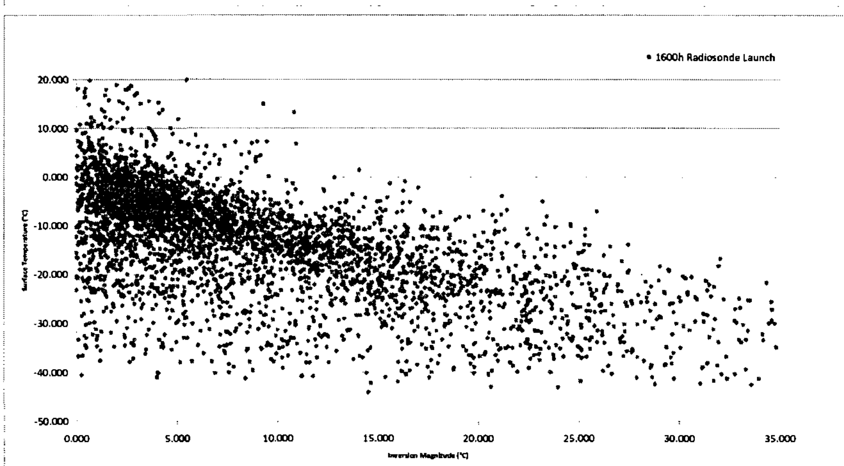


	Daily	0400h	1600h
R Square	0.299781484	0.282141557	0.294374313
Significance F	0	0	0
Coefficients (X Variable 1)	-15.2277265	-13.55419798	-19.35773295
Standard Error (X Variable 1)	0.189085174	0.205469169	0.469491704
P-value	0	0	0

<u>Surface Temperature During an Inversion vs. Inversion Magnitude: 1956-2003</u>







	Daily	0400h	1600h
R Square	0.169938873	0.399595521	0.079309612
Significance F	0	0	3.36851E-75
Coefficients (X Variable 1)	-0.351994616	-0.336127126	-0.430990991
Standard Error (X Variable 1)	0.006320519	0.003915635	0.023003731
P-value	0	0	3.36851E-75

APPENDIX D: Inversion Detection Algorithm in Python 3.0

PYTHON MODULE: INVERSIONDETECTION.PY

```
#               ============
#
#  Abstract:       Inversion Detection and Characterisation Algorithm
#
#  Last update: Tuesday, July 15, 2008. @ 18:34:25.
#
#  File: HXIA-LT::C:/download/InversionDetection.py
#
#  RCS $Header: $
#
#  RCS $Log: $
#
#  Acknowledgement: Huayang Xia and Simon Granger
# ---------------------------------------------------------------------------

"""Inversion Detection Algorithm. (`source code`_).

.. _source code: /python/TxEParser/src/InversionDetection.html

"""

from __future__ import with_statement
import os

SUPPORT_LS = True

if SUPPORT_LS:
   import Scientific.Functions.LeastSquares as LS

# STEPS to perform the task
#
# 1). Get the raw data
# 2). Construct identifiers
# 3). For each identifier, create an object for ResultContainer
# 4). Create a class for ResultContainer, which has the following members
#     a). num182, num183
#     b). _182List, _183List
#     c). flag
# 5). For each object, do the computation.

_DEBUG      = False
_DEBUGOUTPUT = True

rowIDSet   = set([])
rawDataList = []

RowResultContainerList = {}

# ---------------------------------------------------------------------------
FLAG_DUPLICATED   = 1
FLAG_INCOMPLETE   = 2
```

```
FLAG_OTHERS      = 4

class RowResultContainer:        # -- A Row ID'd Result Container --
  """ A Row ID'd Result Container

  """

  def __init__(self, rowID):    # -- Constructor --
    """Constructor

    """
    self.rowID  = rowID
    self.num182  = 0
    self.num183  = 0

    self.LinSlope = 0
    self.LinOffset= 0

    self.flag   = 0

    self._182List  = []
    self._183List  = []

    self.BaseIndex = []
    self.CeilingIndex = []
    self.Strenght = []
    self.Depth = []
    self.ProjectedIntensity = []
    self.ProjectedIntensityError = []
    self.ProjectedIntensityNumElement = []
    self.Magnitude = []

  # ---------------------------------------------------------------------------

  def eleminateInvalidCellsAndFormatData(self):
    """Eleminate the invalid data

      '-99999M' and '12345.6' are deemed invalid data
    """

    Invalid_cell_list = ['-99999M', '12345.6', "-99999", "M-99999M", "-10000272.15", "-9999999",
      "9999.9","9999999"]
    INDEX_ROWCELLS_DATA_START = 5

    # we only handle valid object
    if self.flag:
      if _DEBUG:
        print "flag", self.flag
      return
    rowCells_182 = self._182List[0]
    rowCells_183 = self._183List[0]

    MARK_FOR_DELETION = 'MARK_FOR_DELETION'
```

```
    columns = len( rowCells_182 )
    for column in  range( INDEX_ROWCELLS_DATA_START, columns-1):  # the last column is symbol 'A' or
      'B', so -1
      if rowCells_182[column].strip() in Invalid_cell_list or rowCells_183[column].strip() in
        Invalid_cell_list:  # mark invalid
        rowCells_182[column] =  MARK_FOR_DELETION
        rowCells_183[column] =  MARK_FOR_DELETION
      else:     # change string to float
        rowCells_182[column] = float(rowCells_182[column].strip())
        rowCells_183[column] = float(rowCells_183[column].strip()) #* 0.1
    # remove invalid data
    for cnt in  range( rowCells_182.count(MARK_FOR_DELETION)):
      rowCells_182.remove(MARK_FOR_DELETION)
      rowCells_183.remove(MARK_FOR_DELETION)

    for cnt in  range( INDEX_ROWCELLS_DATA_START ):
      del rowCells_182[0]
      del rowCells_183[0]

  # -----------------------------------------------------------------------------
  #
  def findAllFloorsInRangeAndCeilings(self):
    """Find all floors in range

    """
    if _DEBUG:
      print "=================================================="

    INDEX_ROWCELLS_DATA_START = 0

    # we only handle valid object
    if self.flag:
      if _DEBUG:
        print "self.flag", self.flag
      return
    rowCells_182 =  self._182List[0]
    rowCells_183 =  self._183List[0]

#     print rowCells_182
#     print rowCells_183

    _RANGE_182 = (698, 1250)    # is this the right rule?

    maxIndex183 = len( rowCells_183 )
    # print  maxIndex183

    if maxIndex183 < INDEX_ROWCELLS_DATA_START+2:
      return                    # no enough data

    if maxIndex183 < 15:
      return                    # no enough data
```

```
if _DEBUG:
   print self.rowID
   print "maxIndex183", maxIndex183

# find the start index
for indexStart in  range( INDEX_ROWCELLS_DATA_START, maxIndex183-1):
      if rowCells_182[indexStart] >= _RANGE_182[0]:       # find indexStart to make cell value greater
      than 720
      break

# find the end index
for indexEnd in  range( indexStart, maxIndex183-1):
   if rowCells_182[indexEnd] < _RANGE_182[1]:
      continue
   break                                    # indexEnd make cell value greater than 1250

if _DEBUG:
   print "indexStart", indexStart, "indexEnd", indexEnd

# print "start for one row"
# find all floors
finding_floor = True
for index in range(indexStart+1, maxIndex183-1):
   if finding_floor:
      if index > indexEnd:
         break
      if rowCells_183[index] > rowCells_183[index-1]:
         # print "found index", index
         finding_floor = False
         # print index-1, indexStart
         for potentialFloorIndex in range(index-1, indexStart-1, -1): # find the first of the equal
            series in reverse order
            # print "potentialFloorIndex", potentialFloorIndex
            if rowCells_183[potentialFloorIndex] != rowCells_183[potentialFloorIndex-1]:
               # print potentialFloorIndex
               self.BaseIndex.append(potentialFloorIndex);
               break
   else:
      if rowCells_183[index] < rowCells_183[index-1]:
         self.CeilingIndex.append(index-1);
         finding_floor = True
         break

# have we found any floor
floorNumber = len( self.BaseIndex )

if _DEBUG:
   print "floorNumber", floorNumber

# find strenghts
for aBaseIndex in range(floorNumber):
      self.Strenght.append(rowCells_183[self.CeilingIndex[aBaseIndex]] -
      rowCells_183[self.BaseIndex[aBaseIndex]])
```

```
      self.Depth.append(rowCells_182[self.CeilingIndex[aBaseIndex]] -
        rowCells_182[self.BaseIndex[aBaseIndex]])

    if _DEBUG:
      print "CeilingsNumber", len(self.CeilingIndex)

  # ---------------------------------------------------------------------------

  def findProjectedIntensity(self):

    desiredNumElements = 10

    dataToSend = []
    result = []
    ceilingNumber = len(self.CeilingIndex)
#     print "ceilingNumber", ceilingNumber
#     print "self.CeilingIndex", self.CeilingIndex
    if ceilingNumber > 0:
      for ceilingIndex in range (ceilingNumber):
        desiredNumElements = 10
        numElements = 1
        for index in range(desiredNumElements -1):
          delta = (self._183List[0][self.CeilingIndex[ceilingIndex] + index + 1]) -
            (self._183List[0][self.CeilingIndex[ceilingIndex] + index])
#             print "delta", delta
          if  delta <= 0:
            numElements = numElements + 1
          else:
            break
#           print "numElements", numElements
        if numElements >= 2:
          for index in range(numElements ):
            datatemp =self._182List[0][self.CeilingIndex[ceilingIndex] + index],
              self._183List[0][self.CeilingIndex[ceilingIndex] + index]
            dataToSend.append(datatemp)
#             print "dataToSend", dataToSend
          result = doLinearFit(dataToSend)
          ProjectedIntensity = result[0][0] + result[0][1]*self._182List[0][0]
          self.ProjectedIntensity.append(ProjectedIntensity);
          self.ProjectedIntensityError.append(result[1]);
          self.ProjectedIntensityNumElement.append(numElements);
          magnitude = ProjectedIntensity - self._183List[0][0]
          self.Magnitude.append(magnitude)


#         print "result", result
#         print "result 0 0", result[0][0]
#         print "result 0 1", result[0][1]
#         print "result 1", result[1]
#         print "ProjectedIntensity", ProjectedIntensity

#     print "dataToSend", dataToSend
```

```
    # -----------------------------------------------------------------------------

    def printMe(self):
        """Print the object in a specific way.

        """
        floorNumber = len( self.BaseIndex )
        if (floorNumber > 0) and (self.flag == 0) :
            print self.rowID
            # print self.num182, self.num183, self.flag

            print "Floor indexs", self.BaseIndex
            print "Ceiling indexs",self.CeilingIndex
            print "Strenghts",self.Strenght
            print "Depths",self.Depth
            print "Projected Intensity (Temp, Chi-Squared, Num Elements)",self.ProjectedIntensity,
                self.ProjectedIntensityError, self.ProjectedIntensityNumElement
            print "Magnitude", self.Magnitude


            numElements = len( self._182List[0] )
            for index in range(numElements - 1) :   # remember the last element is "A"/"B"
                print "(%8.1f, %6.3f)" % ( self._182List[0][index], self._183List[0][index]),
            print
            if 0:
                for index in range(numElements - 1) :   # remember the last element is "A"/"B"
                    print "%8.1f," % self._182List[0][index],
                print
                for index in range(numElements - 1) :   # remember the last element is "A"/"B"
                    print "%8.1f," % self._183List[0][index],
                print

            print ""

# -----------------------------------------------------------------------------
def extractRawData() :        # -- Extract the line containing 182 and 183 --
    """Extract the line containing 182 and 183.

    :return:

    """
    global rowIDSet
    global rawDataList

    with open("C:/Python25/CopyData.txt", "rb") as fileinput:
        for line in fileinput:
            rowCells = line.split(',')
            # print columns
            if rowCells[4].strip() == '182' or rowCells[4].strip() == '183' :
                columns = len(rowCells)
                # format the ID
                rowID = "%03d_%02d_%02d_%02d" % (int(rowCells[0].strip()), int(rowCells[1].strip()),
                    int(rowCells[2].strip()), int(rowCells[3].strip()))
```

```
            rowCells[0] = rowID  # put rowID in the first element
            rowIDSet.add(rowID)
            rawDataList.append(rowCells)
    if _DEBUG:
        print rowIDSet
        print
        print rawDataList

# ---------------------------------------------------------------------------
def initialResult() :        # -- Initial the result List --
    """Initial the result List

    :return:

    """
    global rowIDSet
    global rawDataList
    global RowResultContainerList

    for rowID in rowIDSet:
        aRowResultContainer = RowResultContainer(rowID)
        # find out how many _182
        for rowCells in rawDataList:
            if rowCells[0] == rowID:
                if rowCells[4].strip() == '182':
                    aRowResultContainer.num182 += 1
                    aRowResultContainer._182List.append(rowCells)

        # find out how many _183
        for rowCells in rawDataList:
            if rowCells[0] == rowID:
                if rowCells[4].strip() == '183':
                    aRowResultContainer.num183 += 1
                    aRowResultContainer._183List.append(rowCells)

        # initial flag
        if aRowResultContainer.num182 * aRowResultContainer.num183 != 1:
            if  aRowResultContainer.num182 > 1 or aRowResultContainer.num183 > 1:
                aRowResultContainer.flag |= FLAG_DUPLICATED
            if aRowResultContainer.num182 == 0 or aRowResultContainer.num183 == 0:
                aRowResultContainer.flag |= FLAG_INCOMPLETE

        aRowResultContainer.eleminateInvalidCellsAndFormatData()
        aRowResultContainer.findAllFloorsInRangeAndCeilings()
        aRowResultContainer.findProjectedIntensity()

        # assign it to result list
        RowResultContainerList[rowID] = aRowResultContainer

    if _DEBUGOUTPUT:
        if len(list(rowIDSet)):
            IDList = list(rowIDSet)
            IDList.sort()
```

```
        for eachID in IDList:
            RowResultContainerList[eachID].printMe()
if SUPPORT_LS:
    # ---------------------------------------------------------------------------
    def doLinearFit(data) :    # -- Based on the provided points, get the linear fil to make Least Square of the
    points
        """Based on the provided points, get the linear fil to make Least Square of the points.

        :Parameters:
         - `data`: list of points of tuple of ( T, A )

        @returns: a list containing the optimal parameter values
            and the chi-squared value describing the quality of the fit
            [offset, slope, square] for T = offset + slope * A
        @rtype: C{(list, float)}

        >>> data = [(1,2), (2,4), (3, 6)]
        >>> result = doLinearFit(data)
        >>> print "([%08.3f, %08.3f], %08.3f)" % (result[0][0], result[0][1], result[1])
        ([-000.000, 0002.000], 0000.000)
        >>> data = [(1.1,2), (2,4.5), (3.3, 6)]
        >>> result = doLinearFit(data)
        >>> print "([%08.3f, %08.3f], %08.3f)" % (result[0][0], result[0][1], result[1])
        ([0000.388, 0001.771], 0000.492)

        """
        # find the initial parameters from data
        dataLen = len(data)
        if dataLen < 2:
            raise "No enough data. Minimum 2 points, it got", dataLen

        # T1 = o + sA1
        # Tn = o + sAn
        slope_  = (data[dataLen-1][0] -  data[0][0]) / (data[dataLen-1][1] -  data[0][1])
        offset_ = data[dataLen-1][0] - slope_ * data[dataLen-1][1]
        parameters =  (slope_, offset_)

        # get the result
        return LS.polynomialLeastSquaresFit(parameters, data)

# ---------------------------------------------------------------------------
def _test():
    """_test() perform docstring test"""
    import doctest

    extractRawData()
    initialResult()

        return doctest.testmod()
# ---------------------------------------------------------------------------
if __name__ == "__main__":
    import sys
```

```
    def test_displayhook(aData):
        """Just a dummy fct"""
        if aData is not None:
            sys.stdout.write('%r\n' % (aData,) )

    sys.displayhook = test_displayhook

    # Now run the test
    _test()
# ----------------------------------------------------------------------------
```