A comparison of temperature inversion statistics at a coastal and a non-coastal location influenced by the same synoptic regime

A. E. Milionis1, T. D. Davies2

With 13 Figures

Received 10 January 2007; Accepted 29 August 2007; Published online 11 January 2008 © Springer-Verlag 2008

Summary

The primary aim of this work is to examine to what extent the climatology of atmospheric temperature inversions at one location is site specific, and to what extent it reflects a wider area for which the same synoptic conditions can be assumed. To this end radiosonde data from a coastal and a non-coastal location in eastern England separated by 210 km and influenced by the same synoptic conditions are used. Analysis of these data shows that there is a pronounced difference between the inversion climatologies at the two sites. The vertical distribution of base-heights of inversions has a very distinct maximum at a height of about 200 m at the location proximate to the coast. This maximum is not present at the inland location, and the difference is due to both sea-breezes and advection from the sea due to synoptic-scale wind field. Examining the vertical distributions of base-heights of inversions at the two locations under conditions that either maximize or minimize the effect of sea-breeze it is found that the differences in the two distributions are to a certain extent deterministic (therefore predictable) rather than random, as the dominant mechanisms which are responsible for these differences (diurnal and yearly cycles) have an obvious regularity. Using standard statistical methods it is further shown that, apart from this difference, nearly all other inversion statistics for the two locations are similar when the atmospheric layer from surface to 700 hPa is taken into consideration. However, when only the first inversion in each temperature profile is considered, the inversions activity throughout the year, defined with the aid of an index, in the two locations is not correlated, indicating that for the lowest part of the surface-700 hPa region, local factors overwhelm the synoptic conditions. Thus, these results provide evidence that the inversion climatology at one location can be generalised over a wider area where the same synoptic regime can be assumed. Given that, at least to an extent, any differences in the characteristics of inversions due to local factors can be inferred once the underlying mechanisms are carefully studied, this work has also important implications for micrometeorological studies as for instance the local diffusion and transport of air pollutants.

1. Introduction

The development of the climatology of (statistically) stable layers in the lower atmosphere is of importance since, amongst other reasons, it is related to the ability of the atmosphere to inhibit vertical motion. With a few exceptions (Sivaramakrishnan et al. 1972; Nodzu et al. 2006) it is the isothermal lapse rate that is taken as the limiting one, and only layers with negative lapse rates, (the so-called temperature inversion layers), are considered. That happens not so much because there is any strong physical reason for such a separation, but due to the fact that the first stable layer encountered in a temperature profile

Correspondence: A. E. Milionis, Department of Statistics and Actuarial Science, University of the Aegean, Karlovasi 82300, Samos, Greece, e-mail: amilionis@aegean.gr, on leave from the Bank of Greece, Department of Statistics.
is most often an inversion layer (Milionis and Davies, 1992, 1994a). For this reason many studies on the effect of atmospheric conditions on air pollution relate air pollution episodes with temperature inversions (e.g. Kukkonen et al. 2005; Janhall et al. 2006; Malek et al. 2006; Kerminen et al. 2007). Additionally, several of the existing inversion climatologies are restricted to the surface inversions or the first elevated inversions only (e.g. Hosler 1961; Tyson et al. 1976; Preston-Whyte et al. 1977). In our previous research on inversion layers (Milionis and Davies 1992, 1994a, 1994b, 2002, 2007) we used radiosonde data from the U.K. upper air station at Hemsby (52° 39′ N, 1° 41′ E, at an elevation of 14 m) to: (a) establish the main characteristics of the climatology of inversion layers (Milionis and Davies 1992, 1994a, 2002, 2007) and (b) examine their effect on ground-level air pollution (Milionis and Davies 1994b). In order to explain some of the results we made assumptions about the effect of the local topography, in particular the proximity of Hemsby to the North Sea (the upper air station is located 1.5 km from the coast). These assumptions, although reasonable, need further justification, and one way to test for that is to compare the inversion statistics for Hemsby with those from non-coastal stations. As the influence of local factors are expected to affect the statistics of inversions mainly in the first kilometre or so above the ground, this comparison is important particularly due to the significance that the inversion layers of this atmospheric region have in local-scale diffusion and transport of air pollutants.

Although the largest part of the published research work on inversion climatology refers to data from a single location (e.g. Milionis and Davies 1992, 2007; Prezerakos 1998; Abdul-Wahab 2004; Kassomenos and Koletsis 2005), there are several studies on the comparison of inversion climatologies for different locations, in particular coastal and non-coastal locations (Hosler 1961; Preston-Whyte et al. 1977; Nodzu et al. 2006), which are worthy to be briefly reviewed. Hosler (1961), in his study of frequencies of surface and near surface inversions over the contiguous U.S.A., concludes that inversion frequencies at stations in coastal areas reflect marine influences. Low level stability, depending on whether the nearby water surface is colder or warmer that the adjacent land may be either inhibited or enhanced due to advection. As Hosler found, for coastal areas along the south-eastern States and Gulf of Mexico, the formation of inversions is inhibited particularly overnight, while the cold waters of the North Atlantic Ocean cause higher frequencies of inversions at coastal stations, particularly during the day, due to the cool sea-breezes. Preston-Whyte et al. (1977), studying the climatology of the lowest (i.e. first) elevated inversions over Southern Africa, found that the height of the first elevated inversion is greater over the plateau than over coastal areas. They argued that the height at which elevated inversions occur depends not only on the prevailing synoptic situation, but also on the degree of surface heating and upward convective and turbulent mixing. Nodzu et al. (2006) using radiosonde data for a period of 29 years from 14 upper air coastal and non-coastal stations in the Indochina Peninsula investigate the interaction between temperature inversions (more precisely layers with \( \Delta \theta/\Delta z > 10 \text{ K km}^{-1} \)), where \( \theta \) represents the potential temperature and \( z \) the height) and seasonal changes in convective activity during the dry season to rainy season transition. They conclude that the 14 upper air stations can be classified according to three types of vertical thermal stability, by examining the temporal variations of the distribution of the base-height of inversions. As a general rule, however, in all the above mentioned studies differences in the characteristics of inversions for different locations are attributed to the combined effect of topography and the synoptic conditions. Therefore, in that way it is in general not possible to isolate the true effect exclusively due to topography. The only work in which the focus was exactly on the effect of topography is the one of Riordan et al. (1986), who using data from two meteorological towers, compared the strength and frequency of inversions at two dissimilar sites, one of which was on the shore of Lake Robinson in South Carolina, U.S.A., and the other at a top of a hill about 175 km away. Despite the differences in the local conditions, they found many similarities between the inversion climatologies at both sites; for example, high correlation in the day-to-day values of the strength of the inversions in the predawn hours, which indicated an overall synoptic control.