INTERNATIONAL JOURNAL OF ENVIRONMENT
Volume-3, Issue-2, Mar-May 2014 **ISSN 2091-2854**
Received:23 May *Revised:29 May* *Accepted:31 May*

MIXING HEIGHT OBSERVATIONS OVER NAGOTHANE VILLAGE, RAIGAD DISTRICT, WESTERN INDIA

R. K. Kamble
Centre for Higher Learning and Research in Environmental Science,
Sardar Patel College, Chandrapur 442 402, India
Corresponding author: rahulkk41279@yahoo.com

Abstract

Mixing height observations were recorded in Nagothane village of Raigad district of Western India by using minisonde technique in winter season (December 2003-February 2004) at an interval of 3 hours so as to have a clear idea of diurnal variation of mixing heights. The results depicts that maximum mixing height from the study area was 903 m above ground level in afternoon (2.30 pm), while diurnal variation indicated ground based inversions up to a height of about 500 m above ground level, that is nil mixing height during late night (11.30 pm and 2.30 am) and early morning (5.30 am) hours. The diurnal variation of mixing height was in accordance with incoming solar radiation, as the day progresses so the mixing height and vice versa. The maximum mixing height of 903 m above ground level indicated the volume available for dilution, dispersion and transportation of air pollutants in the troposphere which are being emitted by anthropogenic and industrial activities, thus reducing the chances of air pollution episodes in the study area.

Keywords**:** Mixing height, Atmospheric boundary layer, Air pollution, Meteorology, Nagothane, Raigad, Western India

Introduction

The atmospheric mixing height—the layer adjacent to the ground over which pollutants or any constituents emitted within this layer or entrained into it become vertically disperse by convective or mechanical turbulence within a time scale of about a hour (Stull, 1988; Seibert *et al.*, 1998)—at proposed project site is one of the most important micrometeorological parameters, which have direct influence on dilution of air pollutants in the project region. The vertical extent of mixing is primarily regulated by ambient air temperature at ground level, atmospheric stability/turbulence and wind speed. The mixing height at a given time of the day can be estimated from the ground level ambient temperature together with vertical profile of temperature (Anthes, 1978).

In the lower region of atmosphere, the troposphere, the temperature distribution varies considerably depending upon the character of the underlying surface and the radiation at the surface. The temperature may decrease with height (lapse rate) or it may actually increase with height (inversion) depending on the day and land use pattern.

The air quality of a particular region/locality can be managed through control of the air pollution at source after making optimum utilization of the natural dilution and removal (assimilative) capacity of the atmosphere which varies significantly with time and space depending on the meteorological conditions. The dispersion of the pollutant eddies are produced by thermal and mechanical processes. Both type of turbulence are usually present in any given atmosphere condition, either mechanical or thermal turbulence may dominate over the other.

Pollutants emitted into the atmospheric boundary layer or mixing height are gradually dispersed horizontally and vertically through the action of turbulence, and finally become completely mixed over this layer if sufficient time is given and if there are no significant sinks. Therefore, it has become customary in air pollution meteorology to use the term mixed layer or mixing layer or mixing height (MH). Since under stable conditions complete mixing is often not reached, the term mixing layer seems preferable, because it emphasizes more the process than the result. The height ‘h’ of the mixing layer is a key parameter for air pollution models. It determines the volume available for the dispersion of pollutants and is involved in many predictive and diagnostic methods and/or models to assess pollutant concentrations, and it is also an important parameter in atmospheric flow models.

Radio soundings are the most common source of data which can be used to determine the MH for operational purposes. Forecasting of MH is done with the aid of the vertical temperature profile. Radiosonde is a portable atmospheric vertical temperature profile (more than 4 km height) based on *in-situ* measurement technique. *In-situ* measurement is more reliable and has edge over remote sensing technique (2 km only). Radiosonde has potential application in air pollution dispersion studies for determination of site specific mixing height/inversion height as well as ventilation coefficients.

Study area

The Nagothane village is situated in Roha tehsil, Raigarh district of Maharashtra state in Western India. The village is situated in between the villages: Kuhire (North side) and Vadvani (South side) and the Poynad-Nagothane section of State Highway (SH 86) (East side). The study area is basically in the foothills of Western Ghats. The estuarine zone of Amba River and Vadi-Nagothane sections of National Highway (NH 17) as well as Kokan Railway line are falling on the East side at about 1-2 km distance. The topography of the study area was a valley type complex terrain. There were few industrial sources, example MGCC of IPCL, Supreme Petrochemicals, Ispat Ltd. etc. existed within the study area. The vehicular emissions on National Highway and State Highway, commercial activities in Nagothane and domestic emissions in surrounding villages are the prominent air pollution sources in the study area.

Micrometeorology

The micrometeorological data from the study area was recorded on continuous basis during study period (winter season, December 2003 - February 2004) using a battery operated mechanical weather monitoring station. Hourly averages of wind speed, wind direction, ambient temperature and relative humidity were derived from continuous data. The hourly record of wind speed and wind direction data during study period were used for computing the relative percentage frequencies of occurrence in 16 cardinal directions and 5 wind speed classes. These frequencies were computed on 8 hourly as well as 24 hourly basis and the corresponding results were used to draw windroses for 00-08 hrs, 08-16 hrs, and 16-24 hrs, and 00-24 hrs for winter season as shown in figure 1. The 8 hourly windroses during study period (December 2003-February 2004, winter season) showed predominantly calm condition. Wind from N, NW and W directions were observed, with dominant wind speed class of 1-5 kmph. During day time (08-16 hrs) and evening hours (16-24 hrs) there were no significant diurnal variations in wind directions. During night time it was purely calm condition while during day time, wind speed was recorded mostly in the range of 1-10 kmph. The calm condition varied between 35.8% to 99% (8 hourly) with an average of 66.3% (00-24 hrs.) of time during study period. The channeling effect on wind flow was observed near the study area as it was located at the foothills of Western Ghats (wide valley along course of

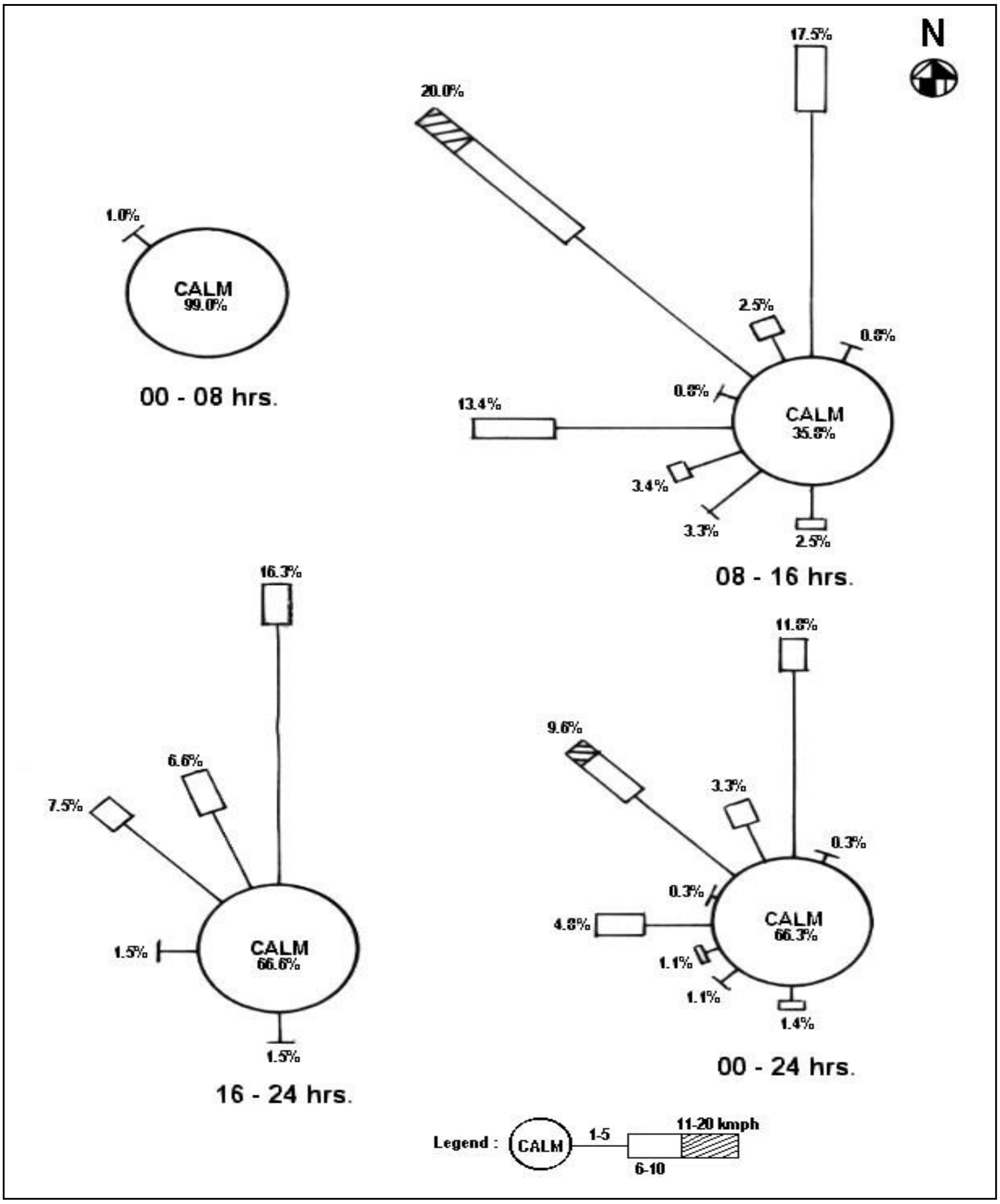

Figure 1. Windrose from the study area (winter season, December 2003 -February 2004)

Amba River). The daily minimum temperature varied between 14°C and 22.5°C while the maximum temperature varied between 22°C and 33.5°C during study period. The relative humidity was observed in the range of 60-85% during study period.

Materials and method

A minisonde system (model 3003 of Aero-Aqua Inc., Canada) was used for onsite measurements of mixing height at sampling site including diurnal variations in winter season (December 2003-February 2004). The minisonde system employs a small light weight sonde, which can be used for measurement of vertical temperature profiles up to 4 km height in the atmosphere by attaching it as payload to a 15 cm balloon filled with hydrogen gas, which can lift the sonde at predetermined ascent rate (3 m/s). The minisonde flight package consisting of balloon filled with hydrogen gas, a battery operated temperature sensor and signal transmitter assembly. Temperature was measured continuously by minisonde and transmitted back at 400 MHz-405 MHz frequency range to a receiving station at ground level. The model 3003 consist an electronic modulator to process non-linearised frequency output from the receiver into linearised signal. The modulator produces actual temperature profile in engineering units which is fed into personal computer through the RS 232 port to obtain real time ambient temperature and potential temperature profiles.

The mixing height study using minisonde was carried out during winter season (December 2003-February 2004). The flight packages were release at the intervals of 3 hr round the clock on each sampling day. The ascent rate of flight package was fixed at 3 m/s (180 m/min) with necessary hydrogen fill. The vertical temperature profiles were continuously recorded till the flight package reaches the altitude of about 3900 m above ground level. These records were used to determine mixing heights representative in the sampling site.

Result and discussion

The diurnal variations in local mixing heights during the study period (winter season, December 2003-February 2004) are depicted in figure 2. During the study period, maximum mixing height was recorded as 903 m above ground level at afternoon (2.30 pm), while diurnal variation indicated ground based inversion up to a height of about 500 m above ground level that is nil mixing height during late night (11.30 pm and 2.30 am) to early morning (5.30 am) hours. The maximum mixing height of 903 m above ground level in the study area indicated the presence of mechanical and thermal turbulence. This shows vertical diffusion of air pollutants hence, ground level concentration of them will be minimum in the afternoon by virtue of dilution, dispersion and transportation in the lower atmosphere—the troposphere. Thus, air pollutants which were released during daytime will get completely mixed up by mechanical and thermal turbulence into the volume of air available for them in the lower atmosphere in the afternoon hours.

A diurnal variation in mixing height from the study area was recorded during sampling period—winter season in a rural background. At 8.30 am, a stable layer was recorded. In this stable layer temperature starts to decline slowly into the lower atmosphere. This decline in temperature was due to radiative cooling of ground surface and formation of a cool layer adjacent to it. In this stable layer mechanical and thermal turbulence was insignificant. The incoming solar radiation during morning hours causes thermal heating of

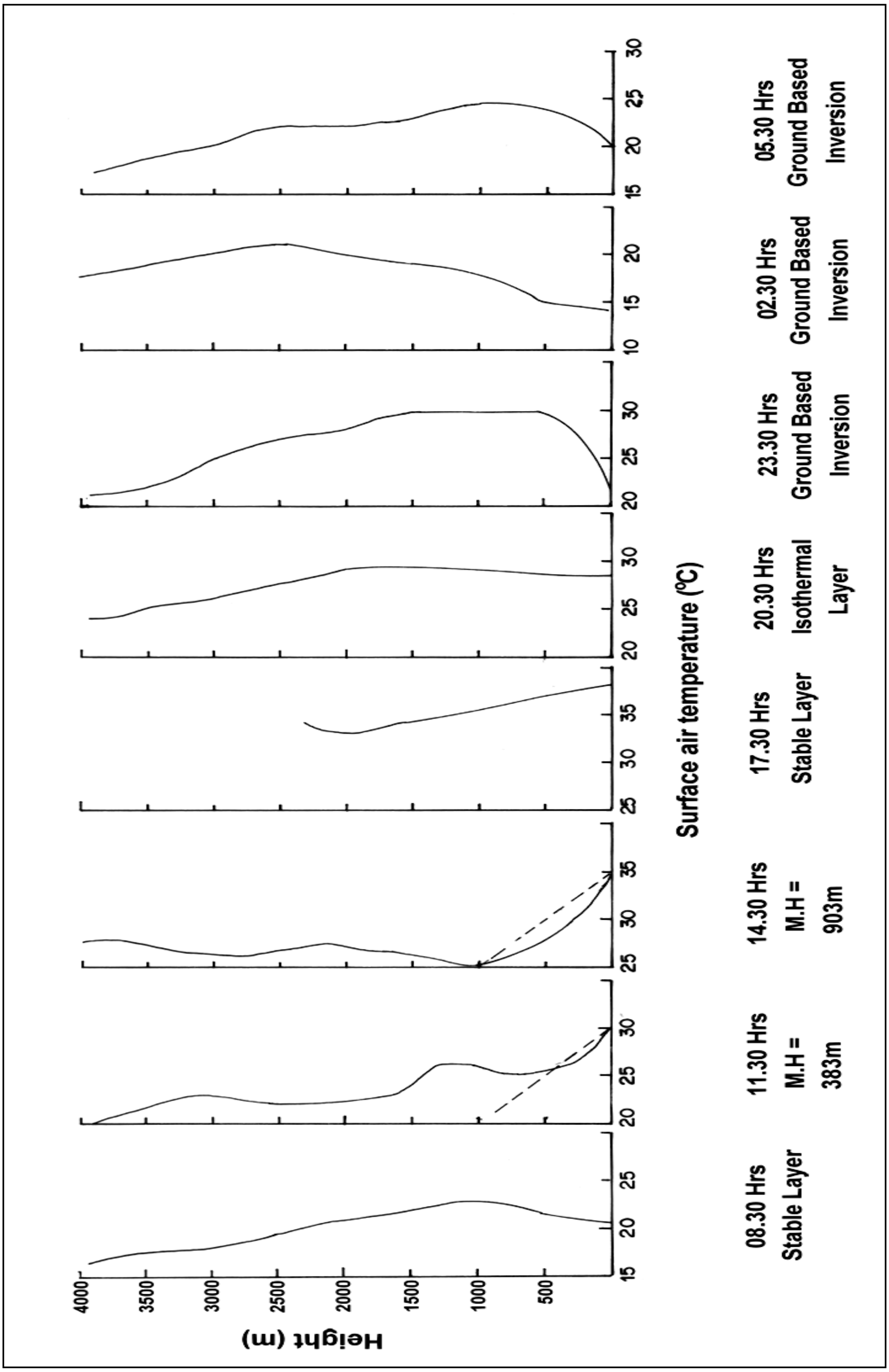

Figure 2. Diurnal variation of mixing height-Winter season

the ground surface. As day progresses incoming solar radiation heats up the ground surface and leads to the formation of convective currents, which is another form of turbulence, leads to breakdown of ground based inversion which was formed at night. At 11.30 am, a mixing height of 383 m above ground level was recorded. Due to incoming solar radiation, ground surface got heated up and leads to the formation of mechanical and thermal turbulence and thus to mixing height. The maximum mixing height of 903 m above ground level was recorded at afternoon (2.30 pm) when ground surface become completely heated up by incoming solar radiation. Daytime mixing height increased with increased heating of ground surface by incoming solar radiation and was maximum in afternoon. Seasonal variations in mixing height are also observed and maximum mixing heights are observed in summer than in winter season. Mixing heights are highest in pre monsoon and lowest in monsoon season. They increased in the post monsoon season to lower again in winter but winter magnitudes are still higher than monsoon season (Padmanabha Murty, 2009). Maximum mixing height of 1650 meters above ground level was observed in Dehra village, Ghaziabad district in Uttar Pradesh during summer 2004 (Kamble, 2012).

Mixing height start to recede towards evening hours as intensity of incoming solar radiation ebb. At 5.30 pm, a stable layer was recorded. As in winter season duration of day is shorter and thus incoming solar radiation, so this stable layer was recorded at late afternoon hour. At late evening (8.30 pm), when there was no incoming solar radiation a isothermal layer above ground level was recorded. During daytime, solar radiation heated up the ground surface and thus even after sun set, thermal radiation continuously gets emitted from it and as a result of which even at late evening hours (after sun set) such a isothermal layer was recorded. In this layer temperature remains more or less steady with height. In this condition the ambient lapse rate was zero, and the atmosphere was stable. At late night (11.30 pm and 2.30 am) and early morning (5.30 am) hours ground based inversion was recorded. An inversion can form from the collision of warm air masses (warm front) with a cold air mass (cold front). The warm air mass overrides the cold air mass in the frontal area, producing the inversion (Manahan, 2000). In this case air movement ceases, stagnation occurs, with a resultant buildup of atmospheric pollutants in localized regions. During nighttime when ground surface started to cool down by radiating thermal radiation, the surface adjoining to ground level was experiencing a higher temperature than the ground surface. As a result of which, ambient air temperature in the vicinity of ground surface was higher than the air layer above it. This resulted in increased in temperature of air and thus leads to ground based temperature inversion (increase in temperature with respect to altitude). This phenomenon continued till early morning by the time ground level got completely cooled down by radiating thermal radiation. Hence, no mixing height was recorded from late night till early morning hours. Inversions are stable and tend to prevent mixing of air pollutants with air above it. In rural areas at night mixing heights are absent (Padmanabha Murty, 2009). Temperature inversion indicated absence of mechanical or thermal turbulence in that particular area, and no volume of air was available for dilution, dispersion and transportation of air pollutants. In temperature inversion condition, if a stack height is below the inversion layer then air pollutants will get trapped below this layer. The incoming solar radiation in this area may trigger the possibility of formation of secondary air pollutants and photochemical smog. Formation of such types of conditions will be more in winter season as compared to summer season, as minimum mixing heights are recorded in winter season as compared to summer season.

Conclusion

The daytime mixing height from the study area was recorded as 903 m above ground level. This indicated that a sufficient volume of air was available for dilution, dispersion and transportation of air pollutants into the lower atmosphere—the troposphere due to the presence of mechanical and thermal turbulence. Air pollutants which got accumulated near ground surface during nighttime due to thermal inversion or nil mixing height will get completely mixed up into the lower atmosphere in afternoon hours when maximum mixing height was recorded. During nighttime due to the thermal inversion or nil mixing height air pollutants may get trapped near the ground surface and in early morning due to incoming solar radiation there may be possibility of formation of secondary air pollutants and photochemical smog which can have an adverse effects on biotic and abiotic components on the surrounding environment in the study area. The mixing height is a decision making parameter for stack height so as to facilitate dilution, dispersion and transportation of air pollutants which are emitted from it and ultimately minimize chances of air pollution episodes in that area.

References

Anthes, R. A., Panofsky, H. A., Cahir, J. J. and Rango, A., 1978. The Atmosphere. Ohio: Charles E. Merrill Publishing Company.

Goyer, G. G. and Watson, R., 1963. The laser and its application to meteorology. *Bulletin of American Meteorological Society*. 44: 564-70.

Grams, G. W. and Wyman, C. M., 1972. Compact laser radar for remote sensing. *Journal of Applied Meteorology*. 11: 1108-13.

Hamilton, P. M., 1966. The use of lidar in air pollution studies. *International Journal of Air and Water Pollution*. 10: 427-34.

Hewson, E. W. Meteorological measurements. In: Stern, A. C. (Ed.) Air Pollution-Air pollutants, their transformation and transformation. Vol. 1, 3rd ed. New York: Academic Press; 1976. p. 563-642.

Kamble, R. K., 2012. Mixing height observations over Dehra village, Ghaziabad district, Uttar Pradesh. *Indian Journal of Environmental Protection*. 32 (4): 299-304.

Lena, F. and Desiato, F., 1999. Intercomparison of nocturnal mixing height estimate methods for urban air pollution modeling. *Atmospheric Environment*. 33: 2385-2393.

Manahan, S. E., 2000. The atmosphere and atmospheric chemistry. In**:** Environmental Chemistry, Lewis Publishers, Boca Raton: CRC Press LLC. pp 280-281.

Padmanabha Murty, B., 2009. Meteorological fundamentals. In: Environmental Meteorology. I K International Publishing House Pvt. Ltd., New Delhi. pp 61-64.

Seibert, P., Beyrich, F., Gryning, S. E., Joffre, S., Rasmussen, A. and Tercier, P., 1998. Mixing layer depth determination for dispersion modeling. In: COST Action 710-Final Report (Eds by B.E.A. Fisher, J.J. Erbrink, S. Finardi, P. Jeannet, S. Joffre, M.G. Morselli, U. Pechinger, P. Seibert and D.J. Thomson). Harmonization of the pre-processing of meteorological data for atmospheric dispersion models. L-2985 Luxembourg: European Commission.

Seibert, P., Beyrich, F., Gryning, S. E., Joffre, S., Rasmussen, A. and Tercier, P., 2000. Review and intercomparison of operational methods for the determination of the mixing height. *Atmospheric Environment*. 2000; 34: 1001-1027.

Strauch, R. G. and Cohen, A. In: Derr, V.E. (Ed.) Remote sensing of the troposphere. National Oceanic and Atmospheric Administration and University of Colorado, Boulder, Colorado; 1972: 23-1.

Stull, R. B., 1988. An introduction to boundary layer meteorology. Kluwer Academic Publishers, Dordrecht.