SEASONAL AND DIURNAL VARIATION IN SO_2 LEVELS CLOSE TO A POWER STATION

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SYNOPSIS

Data obtained from three SO_2 and wind monitoring sites during a 10-month period suggests that episodes occur between 10h00 and 15h00 almost daily, regardless of the synoptic conditions. It is suggested that formation of turbulent eddies cause abrupt increase in concentration levels. These eddies are associated with moderate to high wind speeds. Seasonal and daily SO_2 patterns are discussed.

INTRODUCTION

The growing industrialization and power demand in South Africa is likely to increase air pollution levels, if precautions are not taken in advance. The rate of daily pollution dispersion depends upon the prevailing local and meteorological conditions at the time of release. During predominance of high pressure systems, pollution levels increase over a wide region and vertical dispersion is limited. As wind speeds increase, high concentration levels are likely to be measured close to a source, although dispersion over a wide region may be effective.

In this paper the diurnal and seasonal variations of SO_2 patterns (received from 10-months of measurements) are presented and analyzed, followed by preliminary analysis of the meteorological mechanisms forming these patterns.

TOPOGRAPHICAL CHARACTERISTICS AND DATA SET

Grootvlei power station is situated 90 km SE of Johannesburg and is surrounded by low hills to the north, northeast and southeast.)Figure 1). The station generates through six units 1200 MW at full load and has two 152 m stacks, each serving three units.

Three SO_2 monitoring sites were established equipped with Monitor Labs 8450 analyzers) in the predominant daytime downwind directions; daytime winds were selected because, due to the station's topographical location, the area is affected by nocturnal drainage flow in the lowest 100 m, which does not influence plume behaviour. The sites are situated between 1,6 and 3,1 km away from the power station (Figure 2) and at each site, a 10 m anemometer was erected. The SO_2 data were recorded by charts while the wind data were recorded on magnetic tapes.

Daily surface and upper air meteorological data (comprised of winds, temperatures and pressures) were supplied by the South African Weather Bureau. Surface synoptic charts were given for 08h00 SAST while the upper air data were recorded at midday and midnight. The SO_2 and meteorological data presented in this report include the period of August 1983 to May 1984.

RESULTS

Increase in SO_2 levels at all three sites occurred during the winter and spring (September–October and April–May) while a decrease could be seen during the summer at site 2 (Figure 3). The majority of these episodes (over 95%) occurred during daytime, between 10h00 and 15h00 while nocturnal episodes were rare (Figure 4). The diurnal pattern fluctuated from month to month and site to site but the trend was earlier onset of episodes during the summer, when earlier ground heating took place. The average duration of peaks (1) within each episode was between one and four minutes and on rare occasions five minutes or longer. The average duration of episodes (2) changed from month to month (apart from site 3), a change which could be attributed to differences in local meteorological conditions. On 22% of all episodal days, episodes were recorded at more than one site. These episodes were accompanied by both spatial and temporal fluctuations in wind dirctions. On 60% of these cases, episodes were recorded simultaneously at two sites, implying spatial variability of the wind.

(1) peaks refer to the time in which concentration levels were 0,1 ppm and above.

(2) episodes refer to the overall duration of peaks.

DISCUSSION

Spatial variations in wind directions are not very common during daytime, when synoptic scale winds dominate. During nighttime, both spatial and vertical variations in winds are common, when topography induces flow at lower levels. Since the majority of the episodes were recorded during daytime, the daytime wind flow was dealt with. The diurnal pattern of episodes and the abrupt increase in SO_2 levels are likely to be caused by the increase in mixing depth between ground and stack height levels. As the ground temperature increases, the stable layer comprising the lowest 150-200 m becomes unstable. This instability is characterized by energy and momentum transfer from lower to upper levels, taking place via small scale eddies. These eddies are responsible for the fragmentation of the plume, carrying some fragments upwards and some downwards, giving rise to spiky peaks and a decrease as nearly rapid as the increase (Figure 5).

With temporal and spatial changes in wind directions, SO_2 concentration levels decrease at a specific site. Hourly averages, then, may be low, although spikes of high levels may be recorded momentarialy. The increase in instability is accompanied by increase in low level wind speeds. Episodal occurrences were associated with wind speeds varying between 4 and 10 m/s, the majority being between 4 and 7 m/s. It is interesting to note that at the sites closest to the station (sites 1 and 3), peaks were associated with lower wind speeds (4–6 m/s) than at the farthest site (8–10 m/s). Episodes at site 2 are associated with higher wind speeds because the energy required to carry the plume fragments to a further site is greater.

Most peaks lasted less than five minutes. Those peaks lasting more than five minutes (recorded only at sites 1 and 2), occurred with wind speeds of 1–3 m/s at site 1 and 8–10 m/s at site 3. Again, the increased wind strength needed to carry the fragments to the farthest site is shown.

Since daytime instability occurs nearly everyday (apart from very cloudy conditions during which time temperatures may be isothermal, or neutral), no relationships have been found between synoptic systems and increase in episodal occurrences. During the 10-month period, 52% of all episodes were associated with lows and frontal systems dominating the interior parts of the country, while 35% were associated with high pressure systems. The rest were associated with undefined synoptic patterns. Analysis of the upper air data (800 mb to 600 mb) during episode days did not reveal any significant changes in patterns from those of non-episode days. All noctural episodes, however, were associated with prevalence of low pressure systems at surface and 700 mb, absence of inversions and wind speeds being between 6,3 and 18,5 m/s at 750 mb. This conclusion holds true for measurements taken close to a source.

CONCLUSIONS

Preliminary results from an investigation of the relationships betweeb SO_2 episodes recorded close to a power station and prevailing meteorological conditions suggest the following:

(a) The majority of episodes occur at daytime, between 10h00 and 15h00, and may be related to the increased instability at lower levels and transfer of momentum from lower to upper levels.

(b) Nocturnal episodes, although rare, occur during the prevalence of low pressure systems, high wind speeds and absence of inversions.

(c) Increase in SO_2 levels occurs abruptly and last between one and five minutes in the majority of cases. Hourly averages are, therefore, usually low.

(d) The daily occurence of episodes is likely to be the result of atmospheric instability rather than presence of certain synoptic systems. This conclusion holds true for near source analysis.

More detailed work awaits to be done on eddy sizes and their effects on increase in SO_2 levels.

FIG. 1 Topographical location of Grootvlei Power Station.

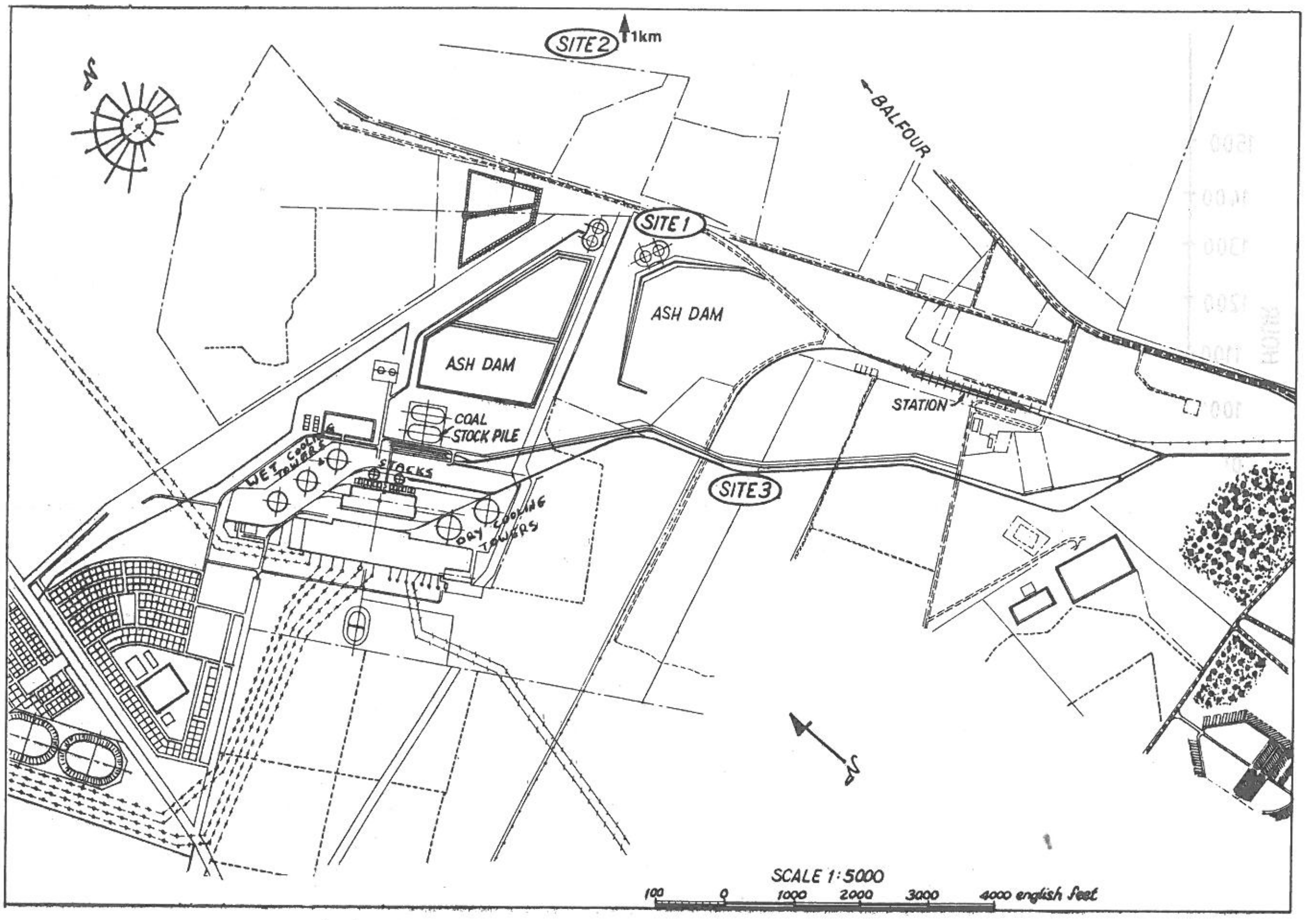

FIG. 2 Grootvlei power station layout and location of monitoring sites.

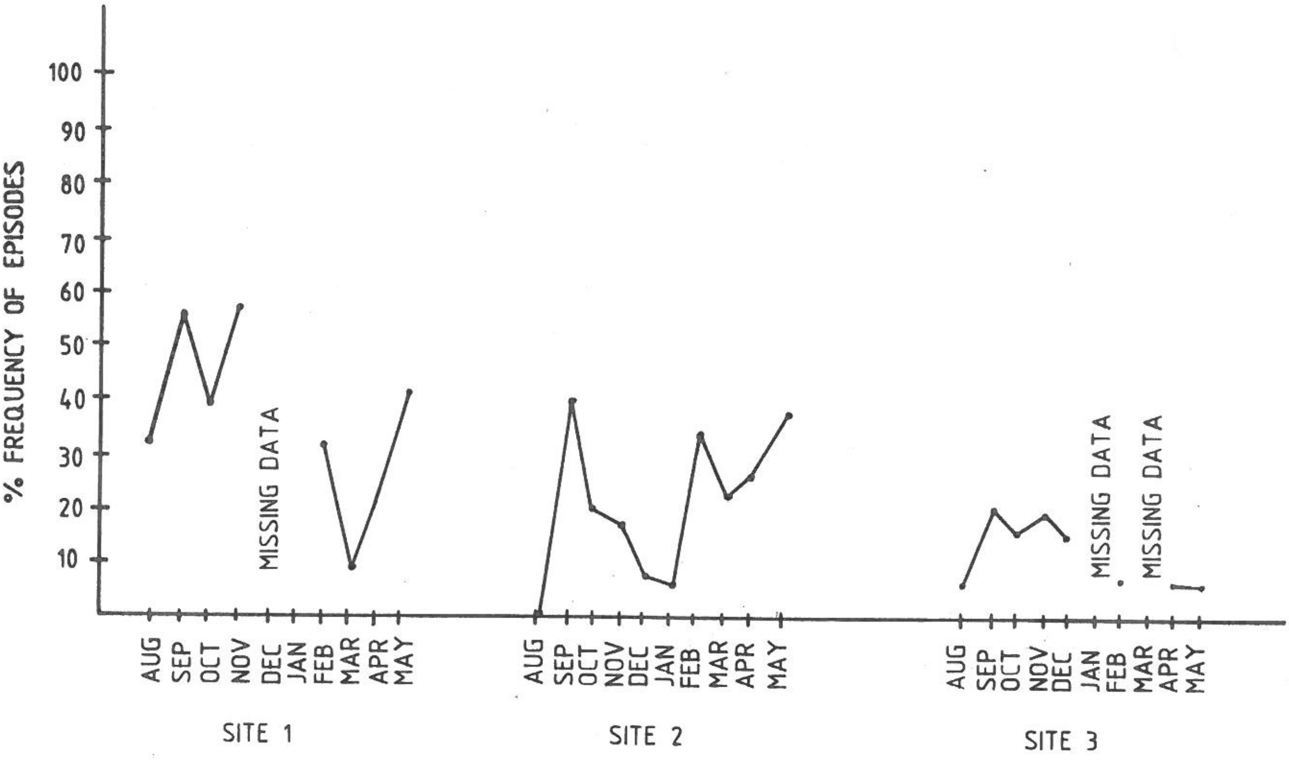

FIG. 3 Seasonal changes in episodal frequency August 1983 – May 1984.

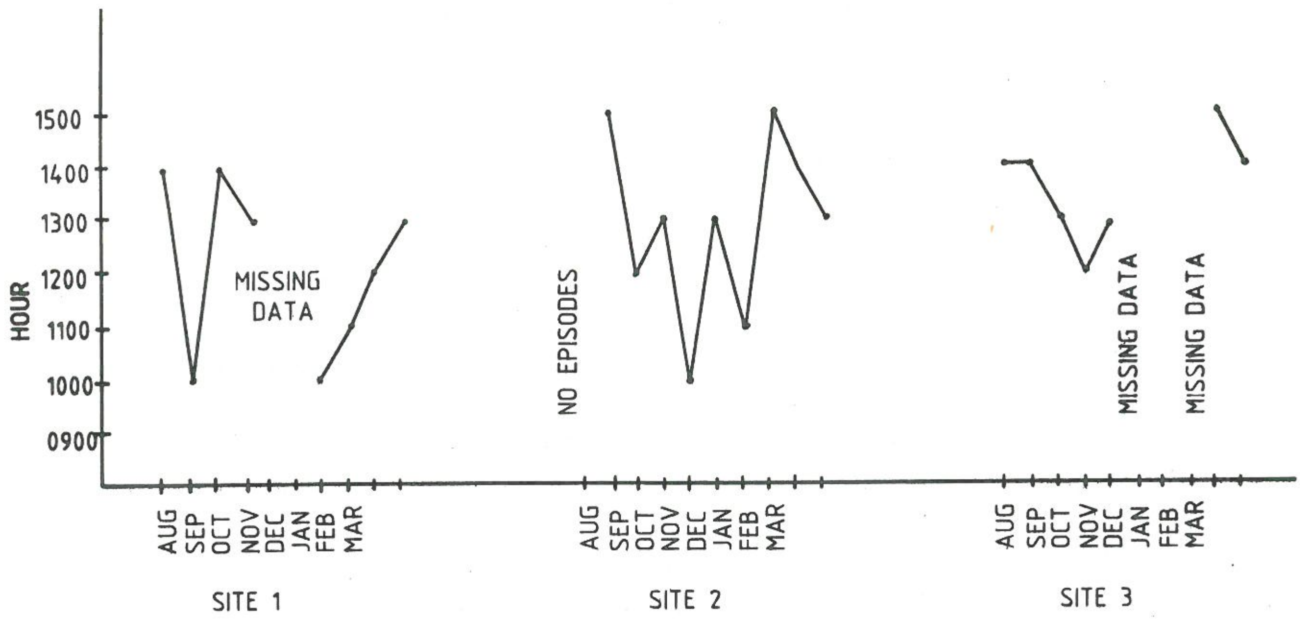

FIG. 4 Seasonal changes in peak episodal hour August 1983 – May 1984

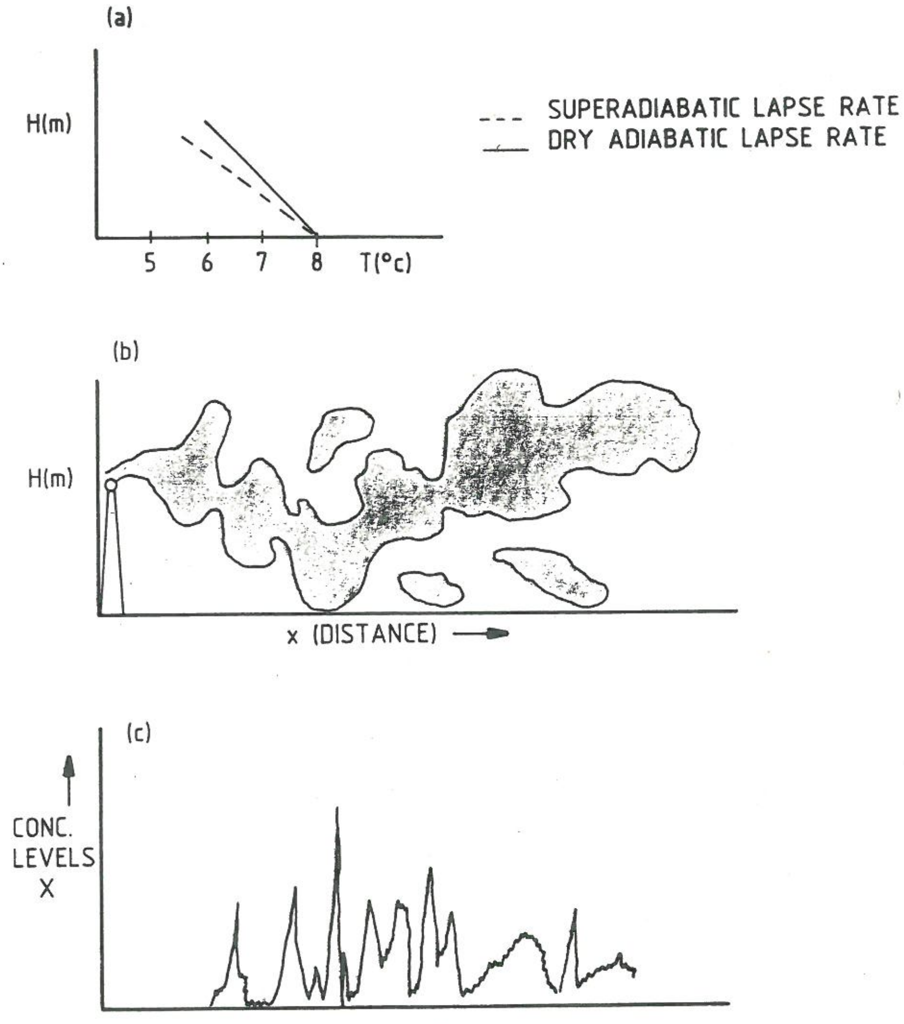

FIG. 5 Plume behaviour during unstable conditions (a), fragmentation of the plume (b) and increasing ground concentration levels due to plume being carried downwards (c).