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COMMUNICATION

ATMOSPHERIC DIFFUSION CHARACTERISTICS AT A COASTAL SITE IN THE TROPICS

E. JAUREGUI*
M. A. VALDOVINOS**
J. M. RODRIGUEZ**
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RESUMEN

Utilizando los datos de temperatura y viento (a 10 y 60 m) de una torre meteorológica ubicada en el sitio costero de Laguna Verde, Ver., se intenta determinar algunas características de la estructura térmica y las propiedades turbulentas de la capa planetaria.

En una situación de 'Norte' el transporte de contaminantes al centro de población más grande (Veracruz) se realizaría en un tiempo corto. Aun cuando la extensión horizontal de la pluma es pequeña en el caso de un Norte, la mezcla en la vertical debida al calentamiento desde abajo fomentaría la dilución.

Tanto la brisa como el terral muestran valores pequeños de la dispersión horizontal. La determinación de categorías de estabilidad por el método de Pasquill resulta en una mayor frecuencia de condiciones de aire inestable en el sitio que la que resulta de aplicar los métodos de delta-t y sigma-teta durante el día. Por la noche se observa una mayor coincidencia entre los métodos de delta-t y sigma-teta.

* *Instituto de Geografía*
** *Ingeniería Ambiental PNLV, CFE*

ABSTRACT

Wind and temperature data (at 10 and 60 m) from a meteorological tower located at a coastal site are used in order to determine some of the thermal and turbulent properties of the boundary layer in the vicinity of a nuclear power plant.

In a 'Norther' condition strong winds would carry air contaminants to Veracruz in a short period. Even though horizontal spread of the plume would be small in this condition, vertical mixing due to heating from below would enhance dilution. Land and sea-breeze winds show small values of horizontal dispersion. The Pasquill method for stability determination gives a higher frequency of unstable air conditions than the delta-t or sigma-theta methods during the day. At night sigma-theta and delta-t methods show better agreement.

1. INTRODUCTION

The first nuclear power reactor in Mexico is at present under construction on a coastal site, in the south-western corner of the Gulf of Mexico (Fig. 1).

An on-site meteorological program has been conducted at Laguna Verde since 1978 following the guide-lines established by International Atomic Energy Agency. The program places most emphasis on the determination of atmospheric stability, based upon the difference in temperature measured between two vertical levels of the atmosphere (10 and 60 m at Laguna Verde site); that is, the so called delta T stability classification procedure.

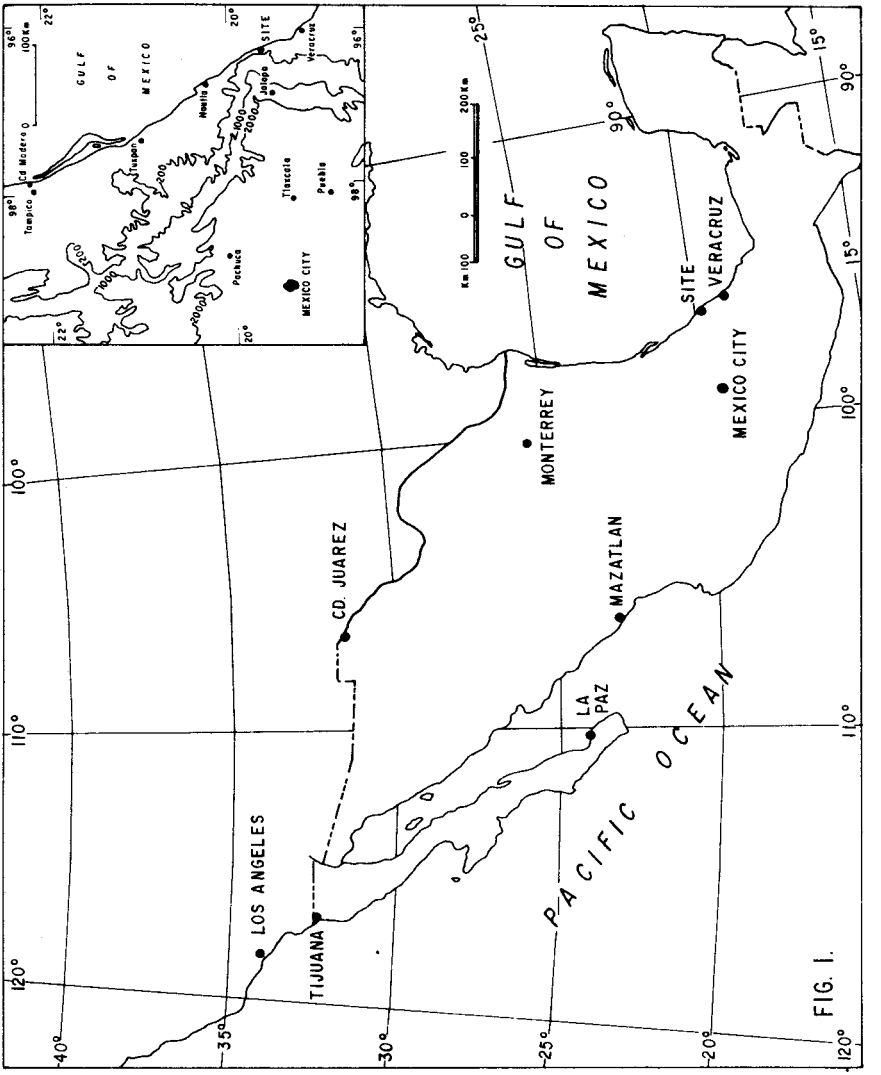
Another stability classification procedure: the so called sigma theta method (Turner, 1969) is also instrumental at the site, so that these two methods can be now compared with each other and also with the more simple Pasquill method (1961), in which stability classes can be derived from ordinary weather observations.

In this paper the turbulent structure of the synoptic and local winds is examined; also an attempt is made to determine how reliable the Pasquill method is with respect to discrimination of atmospheric stability condition at the site, so that a reasonable estimate of the spread of contaminant clouds can be made in case of an accident at the plant. The comparison of the quantitative data with the qualitative estimate would allow a measure of the applicability of Pasquill method to other potential sites in the country, where no other information is available.

2. THE SITE

The Laguna Verde nuclear power plant lies at a point on the coast where the mountains almost reach the sea shore. To the West of the site the terrain raises rather

abruptly to about 400 m, the peaks running east-west with parallel canyons on both sides. To the North and South lie the flat coastal plains.



3. WEATHER SYSTEMS

Even though the site is within the Tropics the weather at Laguna Verde exhibits both tropical and extratropical characteristics. During the winter semester cold, continental (and maritime), polar air masses sweep over the area, producing a conconsiderable drop in temperature and occasionally light rain of frontal type. The strong winds from the North (the Northers) associated with migratory anticyclonic cells from Northamerica often reach gale intensity (near 100 Km/hr) with each frontal passage. A Norther condition would transport contaminants to the port of Veracruz, the largest city nearby (about 150,000 inhabitants) 60 Km to the SSE of site.

The wet season (May to October) begins as the Westerly current retreats to the North giving way to the moist trade winds which are rather light in intensity (Fig.2).

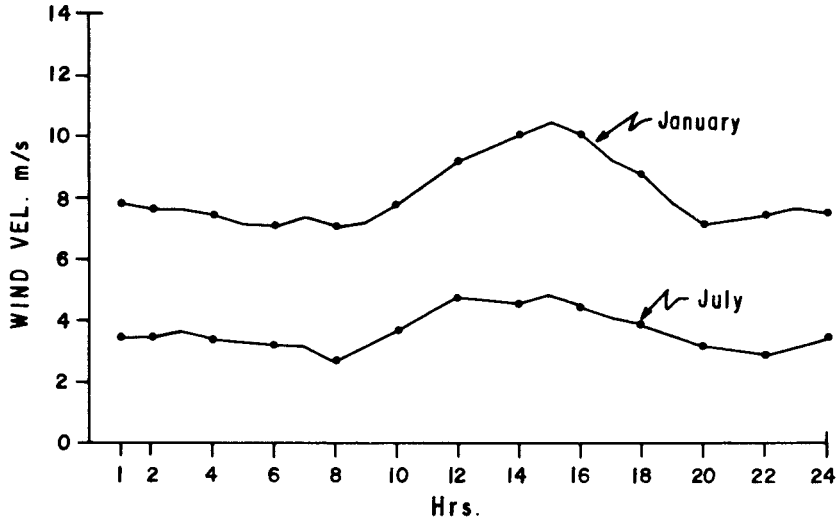


FIG. 2. DIURNAL VARIATION OF WIND VELOCITY AT SITE FOR JANUARY AND JULY 1979.

Rain producing systems during this period are the various wave disturbances, like the Easterly waves and tropical storms, travelling around the SW corner of the Bermuda high.

Also convective clouds formed over the nearly warm shallow waters of the Gulf

precipitate at night or early morning over the coast. The site is also exposed to the devastating (although infrequent) effects of tropical hurricanes. Thus, atmospheric instability in the wake of hurricane BRENDA (19-21 August 1973) produced 144 mm/24 hr at the site.

More recently, hurricane HENRY affected the area and 140 km/hr winds were observed in September 1979 at the site.

4. THE WIND REGIME

Diffusion conditions are generally good during the cold season at the site, as wind intensity varies from 7 m/s in the morning to 9-10 m/s at noon (Fig. 2).

The characteristic diurnal wind direction reversal does not occur during the cold polar outbreaks and although atmospheric diffusion rates increase (in the vertical) in a "Norther" condition, horizontal wind fluctuations show relatively small values (σ_θ= 5° or 7°). The temperature gradient (up to 60 m) is then neutral most of the time due to cold advection over warmer terrain (table 1).

a) *The sea breeze*

Between one polar outbreak and the next, local winds are reestablished, the sea breeze having an Easterly component (Fig. 3). These winds with over-water trajectories (NE to SSE) usually show a near neutral or super adiabatic thermal structure (table 1).

Table 1. Average ΔT (10 to 60 m), sigma theta and wind velocity (at 10 m) for different directions at site for April 1978

	Sea breeze							Land breeze						
	NNE	NE	ENE	E	ESE	SE	SSE	NNW	NW	WNW	W	WSW	SW	SSW
ΔT	-0.8	-0.5	-0.6	-0.5	-0.7	-0.9	-0.3	-0.4	-0.2			–	0.4	0.3
σ_θ	6	8	9	7	8	8	8	7	5	–	–	–	5	7
(m/s)	4	3	3	3	4	4	5	7	7	–	–	–	2	2

The generally smoother water surface would decrease the contribution to diffusion by mechanical turbulence of these winds. On the other hand, however, winds with an Easterly component usually exhibit a near neutral temperature lapse rate (table 1) which would increase the contribution from conventional turbulence. The observed thermal structure of the sea breeze could not be explained in terms of sea-

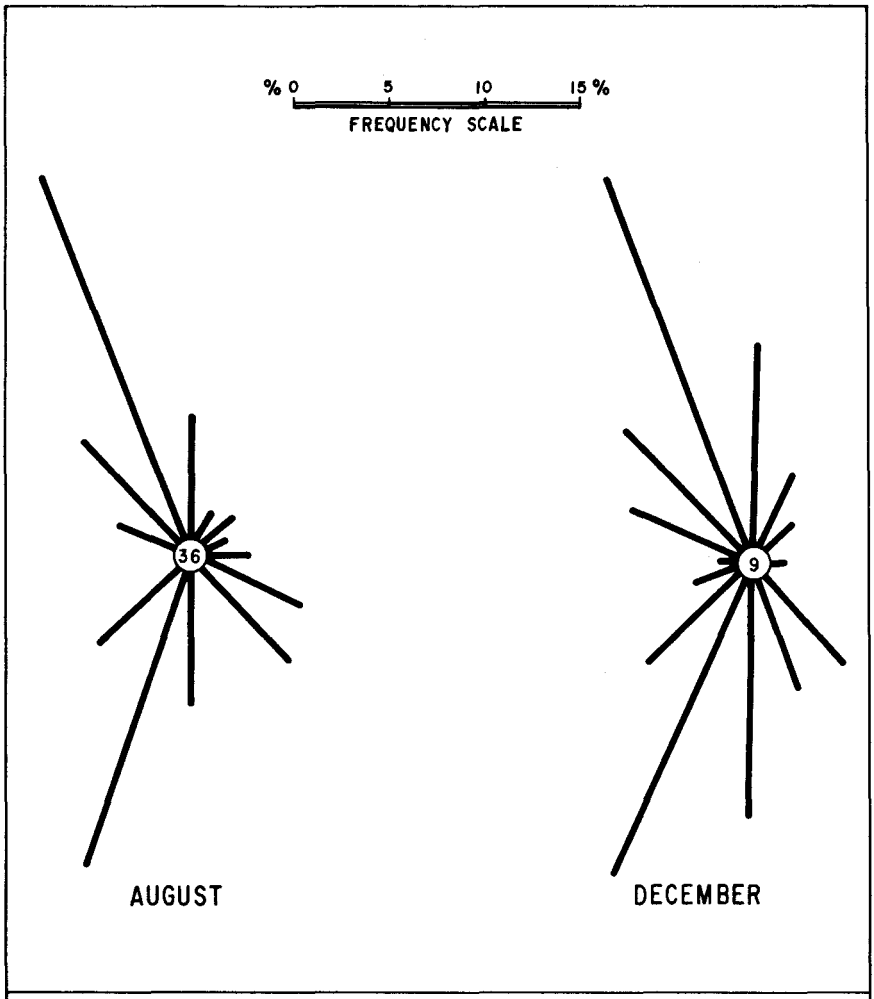


FIG. 3. SURFACE WIND ROSES AT LAGUNA VERDE SITE.

air temperature contrasts. Even though sea surface temperature is usually higher than air temperature in the morning (at 8 am) (Fig. 4) this difference may decrease to zero or even be reversed by noon when the sea breeze is established. Not infrequently however, SST's are higher than air temperature at midday.

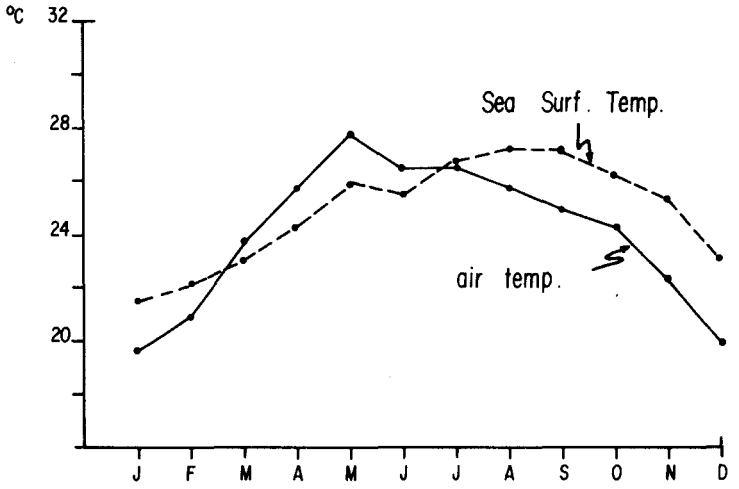


FIG. 4. MEAN MONTHLY SEA AND AIR TEMPERATURES AT LAGUNA VERDE SITE.

A possible explanation for the negative Δ_t would be the rapid heating from below as the marine air reaches the coast line.

The standard deviation of the azimuth fluctuations of the sea breeze (sigma theta) is generally small (6 to 9°) as may be seen in table 1.

In conclusion, it could be said that although mechanical turbulence is small in the sea breeze air at the site, as shown by small σ_θ, the usually unstable thermal structure of these winds would tend to increase the contribution from convectional turbulence.

b) The land breeze

Winds with a westerly component are over-land winds at the site. These winds usually exhibit a positive Δ_t (table 1), that is, stable air is cooled more rapidly over land by nocturnal radiation and flows slowly toward the sea. The observed azimuth fluctuations of the land breeze are also small (5 to 7°) at the site, which is in accordance with its stable thermal structure. The NNW and NW winds are strictly not land breezes; their rather high average intensity shows that they are strong winds associated with the Northers, which blow from this direction at the site. Also, the negative Δ_t indicates advected cold air typical of the Northers.

5. COMPARISON OF STABILITY CLASSIFICATION METHODS AT THE SITE

Figure 5 presents the different distributions of atmospheric stability classes determined for diverse samples of data.

a) *Delta-T and sigma-theta methods*

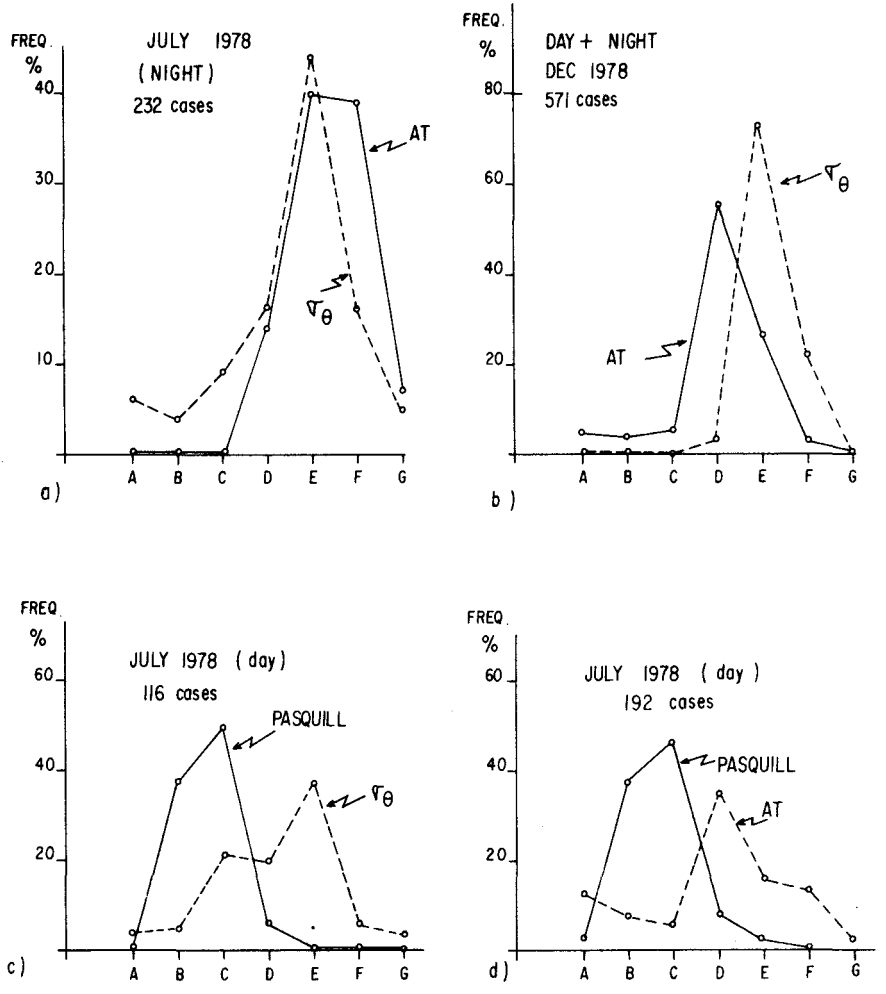


FIG 5. COMPARISON OF STABILITY CLASSIFICATION METHODS

The Δ_t and σ_θ methods are in overall agreement with each other at night when stable air prevails (Fig. 5a). During the day, however (Fig. 5b) a clear majority (about 90 %) of hours were classified as slightly stable or moderately stable (classes E and F) by the sigma-theta method. The sampling time for sigma-theta was one observation of wind direction every three minutes; the standard deviation is computed every 15 minutes. The hourly value is the result of averaging four sigmas in the hour. The Δ_t method for this sample showed a large frequency of neutral or slightly stable classes (Fig. 5b) which should be more in agreement with actual turbulent conditions that prevail during the day at the site.

b) *Comparison of Pasquill method with delta-T and sigma-theta methods.*

In general the stability class distribution based upon Pasquill method was consistently different from either the delta t or sigma approaches for the samples examined (Figs. 5c and 5d). A majority of day hours were classified as moderately unstable or slightly unstable, classes B and C, by the Pasquill procedure. The most frequent stability class for Δ_t and σ_θ being neutral and slightly stable, respectively.

6. CONCLUSIONS

Results of the analysis of meteorological data for the nuclear site at Laguna Verde yield the following conclusions:

a) In a 'Norther' condition transport of contaminants to the largest population center nearby (Veracruz) would take place in a short time. Although horizontal spread of the plume would be small in a Norther, vertical mixing due to surface heating would enhance dilution.

b) Both sea and land breezes exhibit small values of horizontal dispersion; that is, the majority of observed sigma-theta values are consistently small, day or night. This result might have been affected by the sampling time used.

c) Stability class determinations based upon Pasquill approach indicated a greater frequency of unstable conditions at the site during the day hours than do the delta T or sigma methods.

d) There was good agreement between the delta T and sigma theta methods of atmospheric stability determinations at night.

e) Since the majority of day hours at the site were classified as moderately or slightly unstable by the Pasquill procedure, it would be advisable to move at least one

category toward stability when estimating stability conditions for other similar coastal areas in Mexico by this method.

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