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TRANSPORT AND DIFFUSION CLIMATOLOGY OF THE U. S. ATLANTIC AND GULF COASTS

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1. INTRODUCTION

Coastal locations are used for a variety of installations and activities which are actual or potential sources of atmospheric pollutants. Additional facilities and activities are continually being proposed. Installations include nuclear and fossil-fueled power plants, industries and refineries. Activities include oil-drilling, shipment of fuel and transport of hazardous material. Such facilities and activities are commonly concentrated in coastal locations because of proximity to population centers, access to transportation and availability of cooling water.

In the past, sites for such facilities and activities have generally been selected on the basis of economic [illegible]itical considerations with little effort to select locations which would minimize the effects of airborne emissions. In recent years, environmental impact studies are often required after a site has been selected, but usually these merely document existing conditions. Impact studies, particularly for nuclear plants, may affect the design or operating requirements of the plant, but seldom the location. Thus, studies of diffusion are rarely made as part of the site selection process.

This study is part of a larger study of coastal meteorology and diffusion (Raynor, et al., 1975, 1978, 1979) and was planned to assist in site selection by describing the transport and diffusion climatology of the United States east and Gulf coasts in as much detail as can be extracted from readily available meteorological data. Site specific studies may still be necessary for particular locations but the information presented may be adequate to guide a choice between potential sites with respect to air pollution transport and diffusion. No consideration was given in this study to other environmental, economic or political conditions that may also be important in site selection although a planned extension of this study will rate each section of coastline for severe weather potential. The effects on atmospheric diffusion of meteorological processes in coastal zones were discussed previously (Raynor, 1978). A prior presentation (Raynor and Hayes, 1976) briefly described this study and presented some preliminary results. Complete results are given in a more recent report (Raynor and Hayes, 1979).

2. AREA

The area covered in this study is the United States east and Gulf coasts from Maine to Texas. The inland extent of the coastal zone is considered to be that distance to which sea breezes normally penetrate, about 30 km in the north and 60 km in the south. However, boundaries are somewhat indefinite due to the irregular configuration of the coast and the presence of partially or completely enclosed bodies of water such as bays, sounds, harbors and estuaries. The seaward extent of the coastal zone is even more indefinite, but conditions measured on land should probably not be extrapolated more than 10 km offshore without appropriate adjustments, particularly in wind speed and stability.

The region studied is all within the coastal plain and is generally characterized by flat beaches and very gentle slopes inland except in New England where the coast is more rugged and the terrain hilly close to the sea. Local geography should be considered in applying or extrapolating results presented below.

3. VARIABLES

Meteorological variables of primary concern in this study are those which govern or influence transport and diffusion of airborne gases and particles. The most important are wind direction and speed and some measure of diffusive capacity such as turbulence, gustiness or lapse rate. Other important variables are time of year, time of day, latitude, local geography, topography and surface roughness. Not all of these were included in the data available and some that were available were used indirectly, to determine a stability category, for instance.

4. DATA

Data for the study were obtained from the National Climatic Center and consist of hourly or three-hourly synoptic observations usually for consecutive two-year periods from 30 stations from Maine to Texas. The years 1970-1971 were obtained for most stations. Stations were selected to give a reasonably continuous and evenly spaced distribution along the coast while avoiding non-representative locations as much as possible. Moreover, selection was limited to those stations for which data on tape were available. (Table 1)

Eight stations were chosen to give four pairs for comparison between a coastal station and another somewhat farther inland. The pairs are Boston and Bedford, Massachusetts; Belmar and Lakehurst, New Jersey; Cape Kennedy and Orlando, Florida; and Galveston and Houston, Texas. The same years of data were obtained for both stations in each pair.

5. ANALYTICAL METHODS

[S]ynoptic data were converted to forms most useful for the purposes of this study. Wind directions were divided into eight numbered classes relative to the coastline nearest to the station. For some analyses, these eight classes were combined into three: onshore, alongshore and offshore. Wind speeds were grouped into five classes, calm, 0.5-2.4, 2.5-4.9, 5.0-9.9 and ≥10.0 m sec^{-1}.

A stability class was calculated for each observation using a modification of the Pasquill-Gifford method described by Turner (1964) by modifying the STAR computer program obtained from the National Weather Service. The original program uses date, time of day, geographic location, total sky cover, ceiling height and wind speed to compute a stability class. Modifications used here were described earlier (Raynor and Hayes, 1978). For some analyses, the eight classes were combined into three: unstable, neutral and stable.

For classifying the data by season, four classes were formed: spring, March-May; summer, June-August; fall, September-November; winter, December-February. The data were also divided into day and night classes. In order to obtain the best agreement between these classes and atmospheric stability, day is considered the period from one hour after sunrise to one hour before sunset as used in the STAR program.

A diffusion rating classification was derived from a combination of the wind speed and stability classes. Diffusion rating classes were determined from ranges of dilution factors ($\bar{u}$, σ_y, σ_z) at 1 km. Values of σ_y and σ_z at 1 km were taken from Turner (1964). The divisions selected in this way agreed well with subjective determinations of several meteorologists experienced in diffusion studies. The diffusion rating was used as another variable. Finally, the joint frequency of the wind direction classes and the diffusion rating classes was computed.

For each station, percentage frequency distributions were computed for selected variables or combinations of variables as follows: The percent of hours in each of the three combined wind direction classes and the percent with calm winds were determined by season and time of day. The percent of hours in each of the three combined stability classes by the combined wind direction classes and wind speed was computed for all hours with non-calm wind speeds. The percent of hours in each of the eight stability classes by the combined wind direction classes, season and time of day was calculated for all non-calm hours. The percent of hours in each wind speed class by the combined wind direction classes, season and time of day was determined for all non-calm hours. The percent of hours in each diffusion rating class by combined wind direction class, season and time of day and the joint percentage frequency of hours in each combination of wind direction class and diffusion rating class was also computed.

6. RESULTS

Complete results are included in a report by Raynor and Hayes (1979). Only selected examples are presented here.

The frequency of calms and of winds in the three sectors relative to the coastline is shown in Figure 1 for the 25 coastal stations

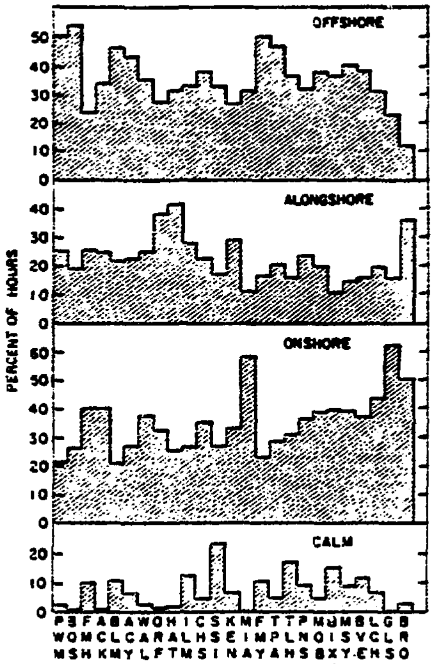

Fig. 1. Percent of hours in each wind direction class at 25 coastal stations.

from Portland, Maine (PWM) to Brownsville, Texas (BRO). Onshore winds are most frequent on the east coast of Florida and the Texas coast and least frequent in New England, New Jersey and the west coast of Florida. Calms occur over 10% of the time at 8 stations but very seldom at Miami and Galveston. The same information was computed as a function of season but is not included here.

Differences between day and night in wind direction distribution are shown in Figure 2 for six selected stations. At each, onshore winds are more frequent in the daytime, largely due to the sea breeze effect. Offshore winds and calms are more common at night. Similar differences were found for the other stations.

The frequency of the five diffusion rating classes at the same coastal stations during onshore winds is shown in Figure 3. Poor diffusion conditions as computed from dilution factors occur more frequently than good conditions at most stations. Among the better stations are Wallops Island, Biloxi and Galveston. Poor conditions predominate at Norfolk, Charleston and Brownsville. The same information is available for the other wind direction sectors and for all directions combined.

Differences in diffusion conditions between day and night at six selected stations are shown in Figure 4. Good conditions are more frequent during the day and poor conditions during the night. These differences are representative of the other stations not shown.

The percent of hours in which effluents could be released with little concern for adverse effects is a function of combined wind direction and diffusion conditions as shown in Figure 5. Such conditions are most frequent in New England, at Cape Hatteras and along the west coast of Florida and least frequent along the Georgia and east Florida coast.

Data from the four coastal-inland pairs show that calms and poor diffusion conditions are more frequent inland but onshore winds are less frequent. Considering wind directions and diffusion conditions jointly, however, favorable release conditions are somewhat more frequent at the coast.

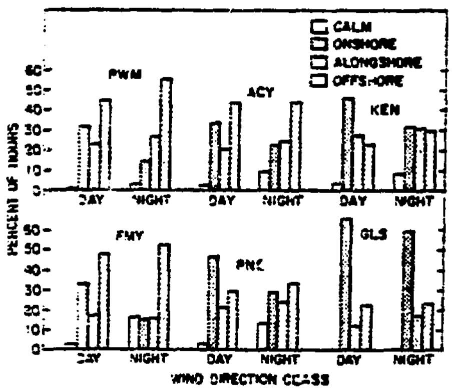

Figure 2. Percent of hours in each wind direction class at six stations by day and night.

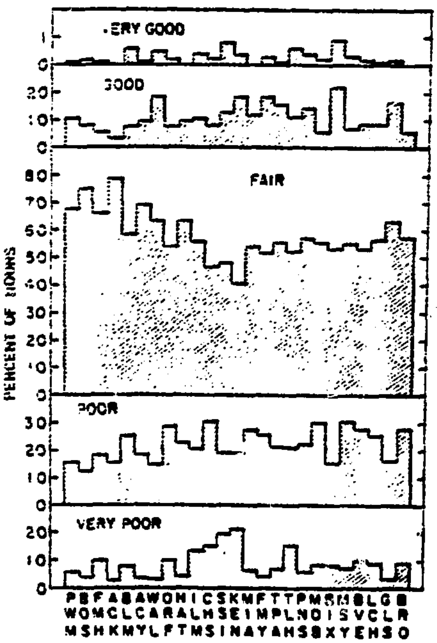

Figure 3. Percent of hours in each diffusion rating class at 25 coastal stations during onshore winds.

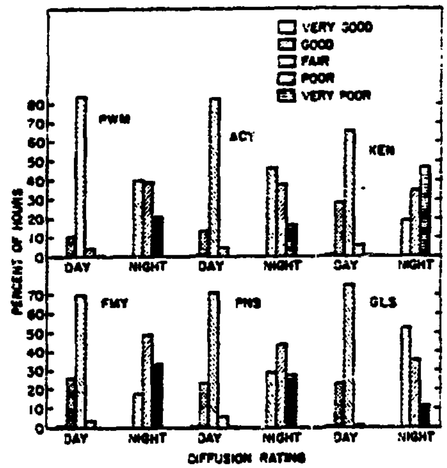

Figure 4. Percent of hours in each diffusion rating class at six stations by day and night.

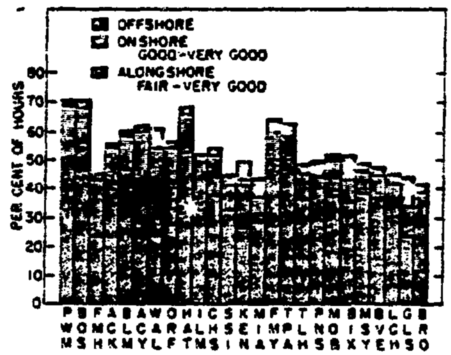

Figure 5. Percent of hours in favorable wind direction and diffusion rating classes at 25 coastal stations.

7. APPLICATION AND FUTURE WORK

The results obtained were arranged for easy use with diffusion models in which the primary meteorological inputs are wind speed and measures of lateral and vertical diffusion. The latter can readily be derived from the stability classes by established relationships. Presentation of data by season, time of day and wind direction classes permits ready selection of the other meteorological parameters for any desired combination of conditions. Interpolation can be employed for locations between stations. Use of the information in the detailed report may permit preliminary site evaluation without diffusion modeling.

Additional studies are planned as part of this investigation. An attempt will be made to determine and classify diffusion conditions over the water which may be quite different from those over land. Data from lightships and other sources will be used. The frequency of several types of severe weather will be determined as a function of location along the coast. Data from Brookhaven National Laboratory and several outlying stations will be analyzed to fill in the gap between New England and New Jersey and to compare results from an east-west coastline with those from nearly north-south coastlines.

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TABLE 1
Locations of Stations

Station	Designation
Portland, ME	PWM
Boston, MA	BOS
Bedford, MA	BED
Falmouth, MA	FMH
Nantucket, MA	ACK
Belmar, NJ	BLM
Lakehurst, NJ	NEL
Atlantic City, NJ	ACY
Wilmington, DE	ILG
Wallops Island, VA	WAL
Norfolk, VA	ORF
Cape Hatteras, NC	HAT
Wilmington, NC	ILM
Charleston, SC	CHS
Brunswick, GA	SSI
Cape Kennedy, FL	KEN
Orlando, FL	ORL
Miami, FL	MIA
Ft. Myers, FL	FMY
Tampa, FL	TPA
Tallahassee, FL	TLH
Pensacola, FL	PNS
Mobile, AL	MOB
Biloxi, MS	BIX
New Orleans, LA	MSY
Boothville, LA	BVE
Lake Charles, LA	LCH
Galveston, TX	GLS
Houston, TX	HOU
Brownsville, TX	BRO