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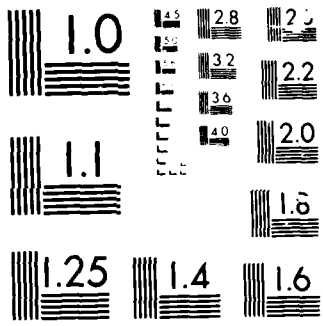
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A SIMULATION FEASIBILITY STUDY

by

2d Lt Kevin L. Witte

JUNE 1986



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SUMMARY

This document was prepared by the USAF Environmental Technical Applications Center's Environmental Simulation Section (USAFETAC/DNY) in response to a 13 February 1986 AWSR 105-18 request from the Air Force Aerospace Medical Research Laboratory. To satisfy the request, USAFETAC performed a feasibility study to investigate methods of modeling cloud cover, wind speed, and wind direction.

The author concluded that wind speed and wind direction should be modeled together, but that cloud cover should be modeled separately because of the low correlation between cloud cover/wind speed and cloud cover/wind direction. The author also concluded that wind speed and cloud cover can be used to simulate a Pasquill Stability Index.

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ABSTRACT

The results of a pilot study to assess the feasibility of simulating wind speed, wind direction, and Pasquill Stability Indices are presented. These results are positive, and suggest that a two variable single station simulation model could be used to model wind speed and wind direction. Simultaneously a cloud cover simulator could be run to produce a Pasquill Stability Index.

OBJECTIVES AND RESEARCH FRAMEWORK

The feasibility study had the following specific objectives:

- 1) To assess the difficulty of modeling wind speed, wind direction, and cloud cover.
- 2) To conduct an extensive literature search in order to review works which have preceded this effort.

The objectives were pursued in two stages. The first stage was to review in-house literature on your 105-18 request and task the Air Weather Service Technical Library (AWSTL) to do a literature search in the area of modeling wind speed, wind direction, and cloud cover. The Somerville models were reviewed for applicability, as well as the documents sent to me by the AWSTL. The second stage of the study involved an analytic investigation of data for several West German stations. The majority of the time spent on this project included reviewing literature and running computer programs.

SUMMARY OF RESULTS

The results of the literature search suggest that cloud cover is best modeled using Beta curves (NASA CR-161490), wind speed is primarily modeled with Weibull Distributions (AFGL-TR-79-0180). No literature was found that deals with wind direction modeling.

The following histograms are frequency distributions of the variables of interest. The wind speed distributions appear to fit a Weibull distribution, as shown in Figs. 1-5. This is in agreement with previous studies done on this subject by Somerville and Bean. Figures 1-4 show that the mid-season monthly variations in frequency distributions of wind speed are negligible. Figure 5 is the sum total wind speed frequency distribution for all months. Wind direction is a bimodal distribution (See Figs 6-10). Wind direction does vary with season. This fluctuation will be taken into account by adjusting input variables of the Beta function. The spikes in the data at points N, E, S, W are in reality smaller than shown. This exaggeration in the data is attributed to observer bias. Figure 10 is a summation of the frequency distribution of wind direction. Cloud cover fits a Beta distribution (See Fig 11). Cloud cover cumulative frequency distributions vary from site to site. However, Beta probability density functions have the mathematical flexibility to assume a variety of shapes. Beta curves can be mound shaped, U-shaped, or J-shaped with varying amounts of skewness.

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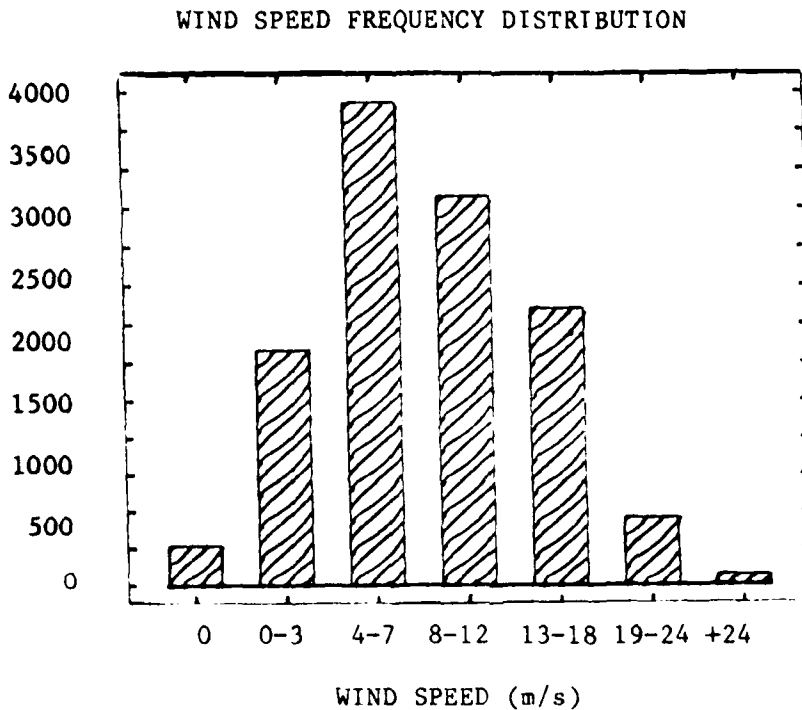


Figure 1. Histogram of wind speed frequency distribution for 10 year period of record (January) for Hanover Germany.

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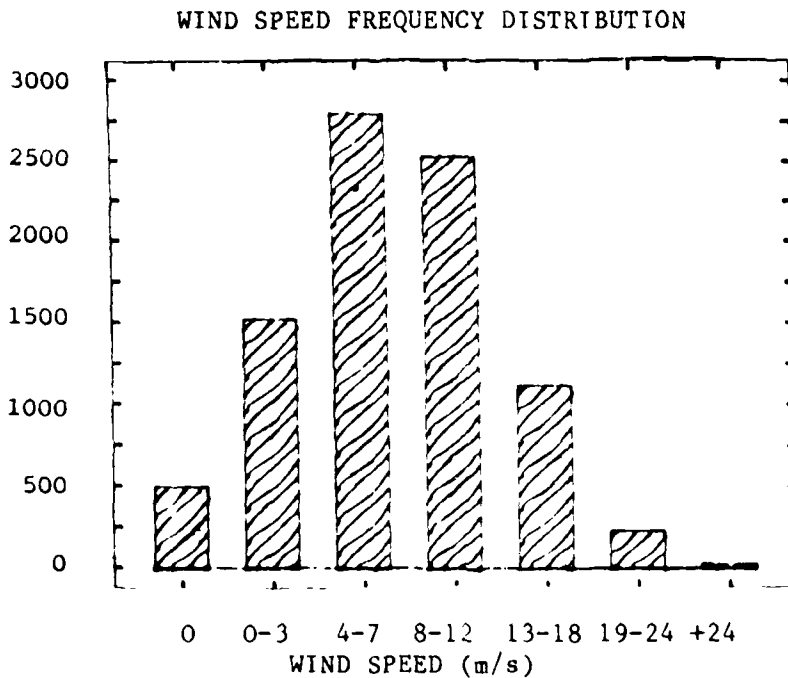


Figure 2. Histogram of wind speed frequency distribution for 10 year period of record (April) for Hanover Germany.

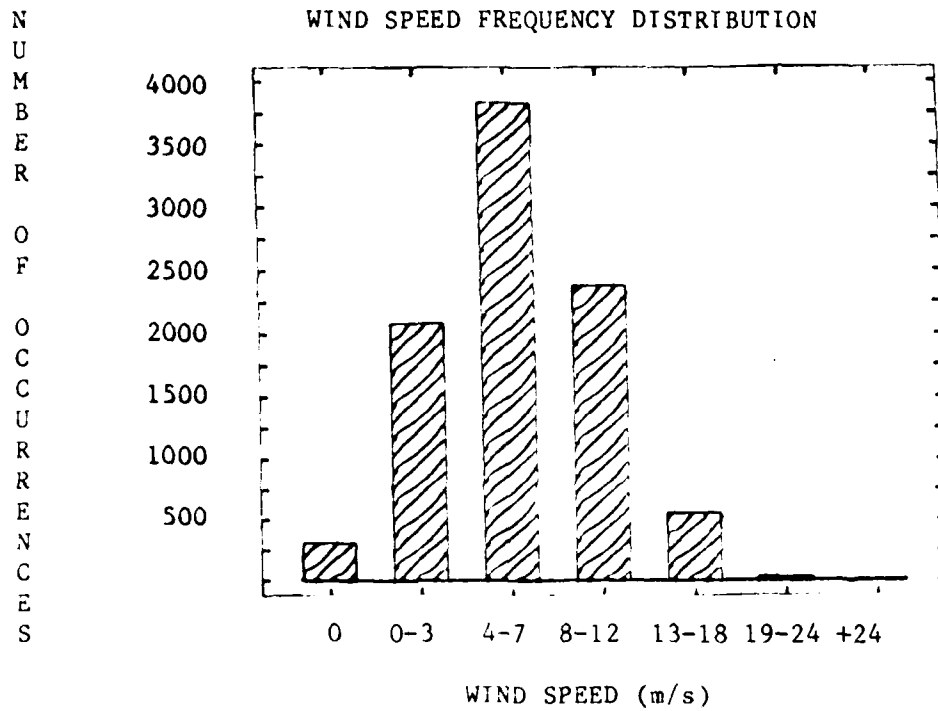


Figure 3. Histogram of wind speed frequency distribution for 10 year period of record (July) for Hanover Germany.

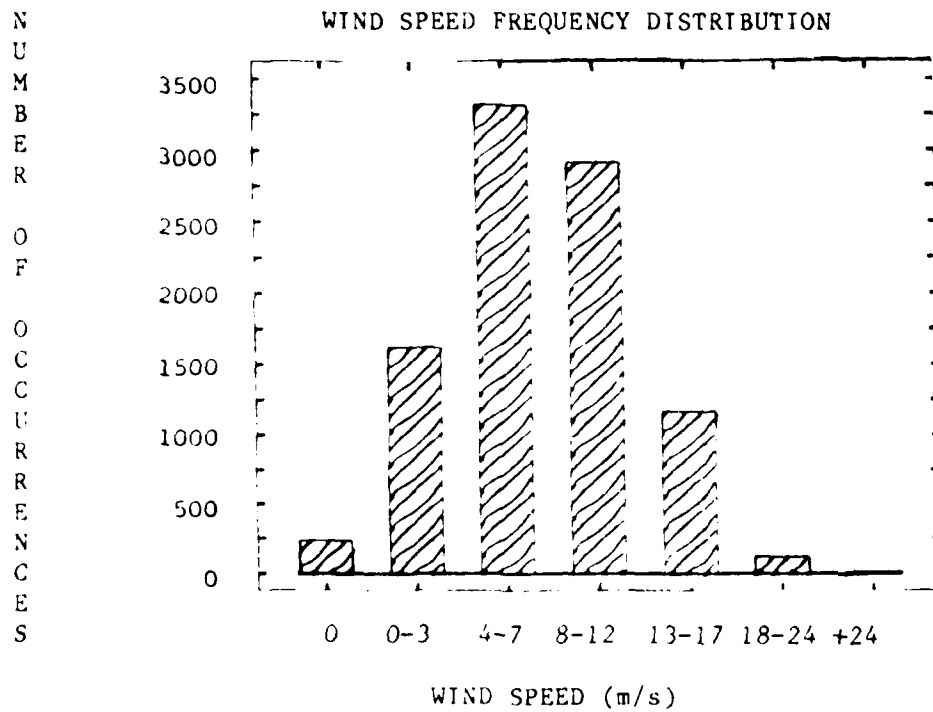


Figure 4. Histogram of wind speed frequency distribution for 10 year period of record (October) for Hanover Germany.

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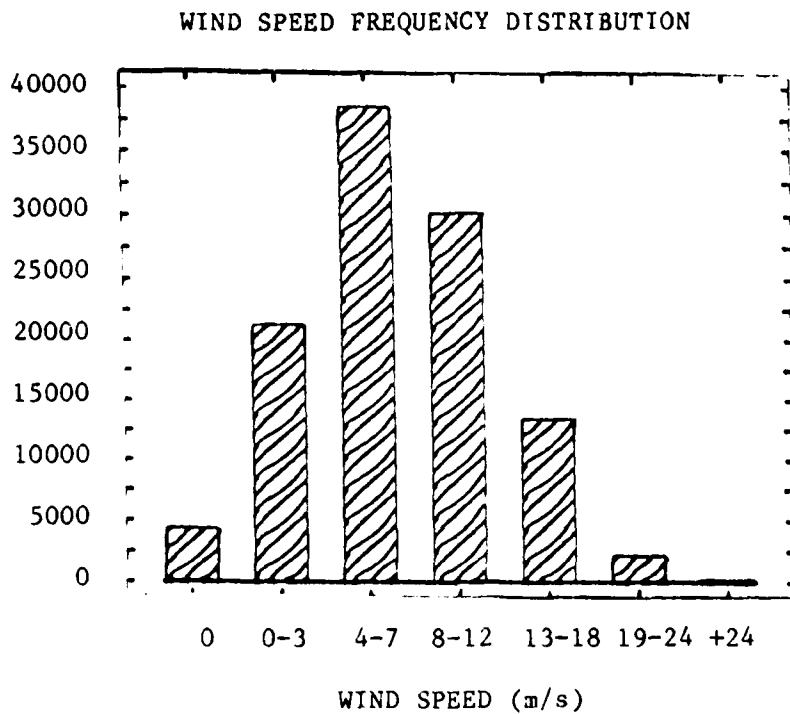


Figure 5. Histogram of wind speed frequency distribution for 10 year period of record for Hanover Germany.

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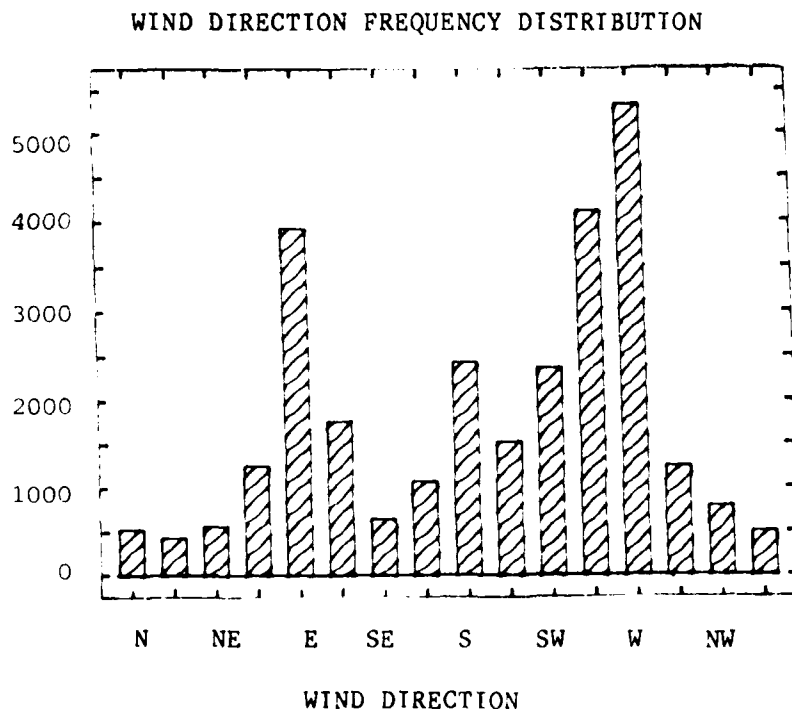


Figure 6. Histogram of wind direction frequency distribution for 10 year period of record (January) for Hanover Germany.

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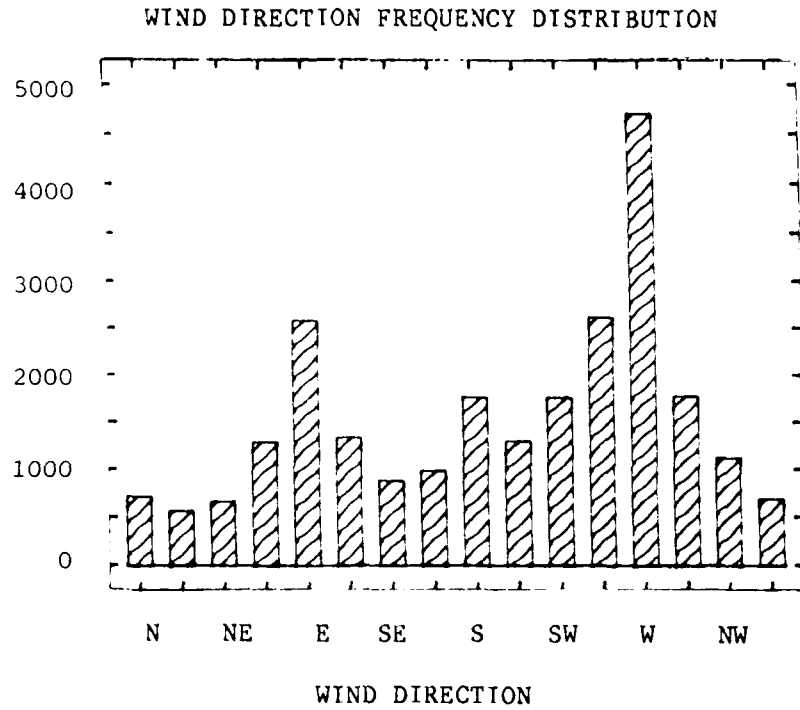


Figure 7. Histogram of wind direction frequency distribution for 10 year period of record (April) for Hanover Germany.

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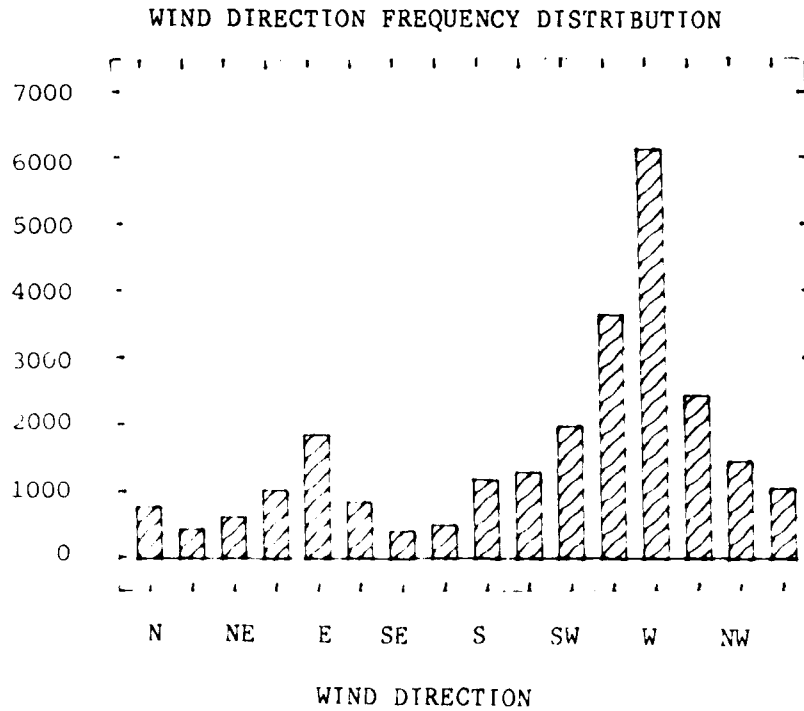


Figure 8. Histogram of wind direction frequency distribution for 10 year period of record (July) for Hanover Germany.

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WIND DIRECTION FREQUENCY DISTRIBUTION

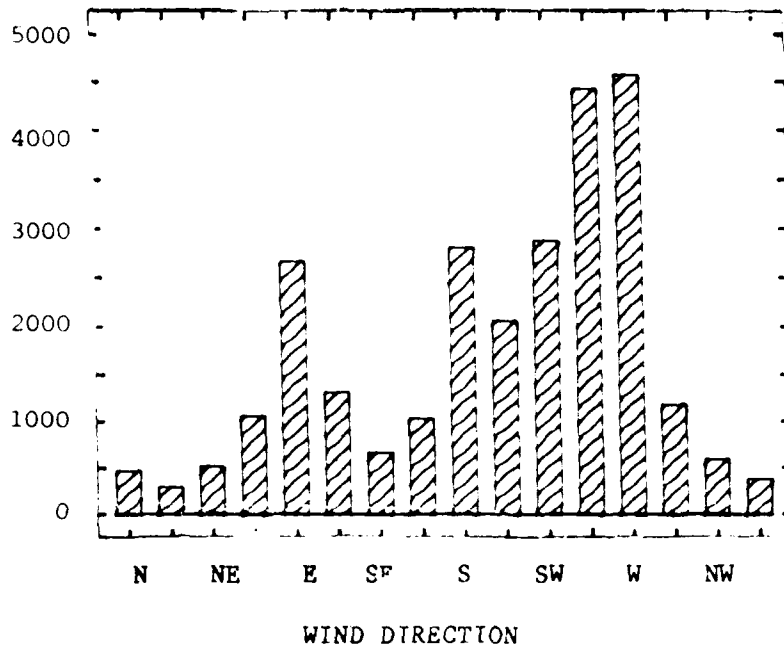


Figure 9. Histogram of wind direction frequency distribution for 10 year period of record (October) for Hanover Germany.

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WIND DIRECTION FREQUENCY DISTRIBUTION

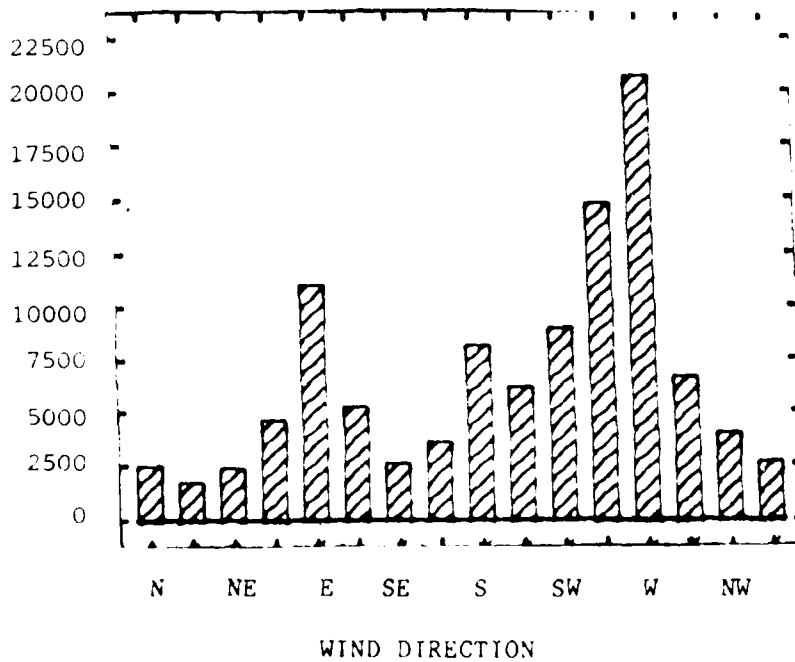


Figure 10. Histogram of wind direction frequency distribution for 10 year period of record for Hanover Germany.

CLOUD COVER FREQUENCY DISTRIBUTION

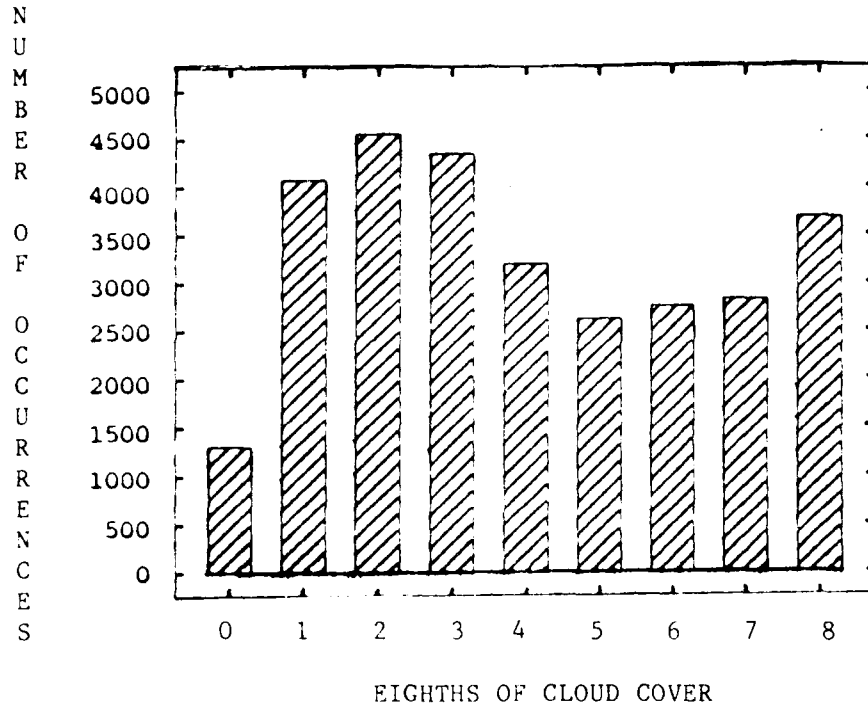


Figure 11. Histogram of cloud cover frequency distribution for 10 year period of record for Hanover Germany.

To fit the raw data to theoretical distribution curves, an in-house curve fitting program (QQPLOT) was used. This program transforms the raw data, and graphically presents the optimum curve from a choice of six: Beta, Gamma, Single and Double Johnson, Normal, and Weibull.

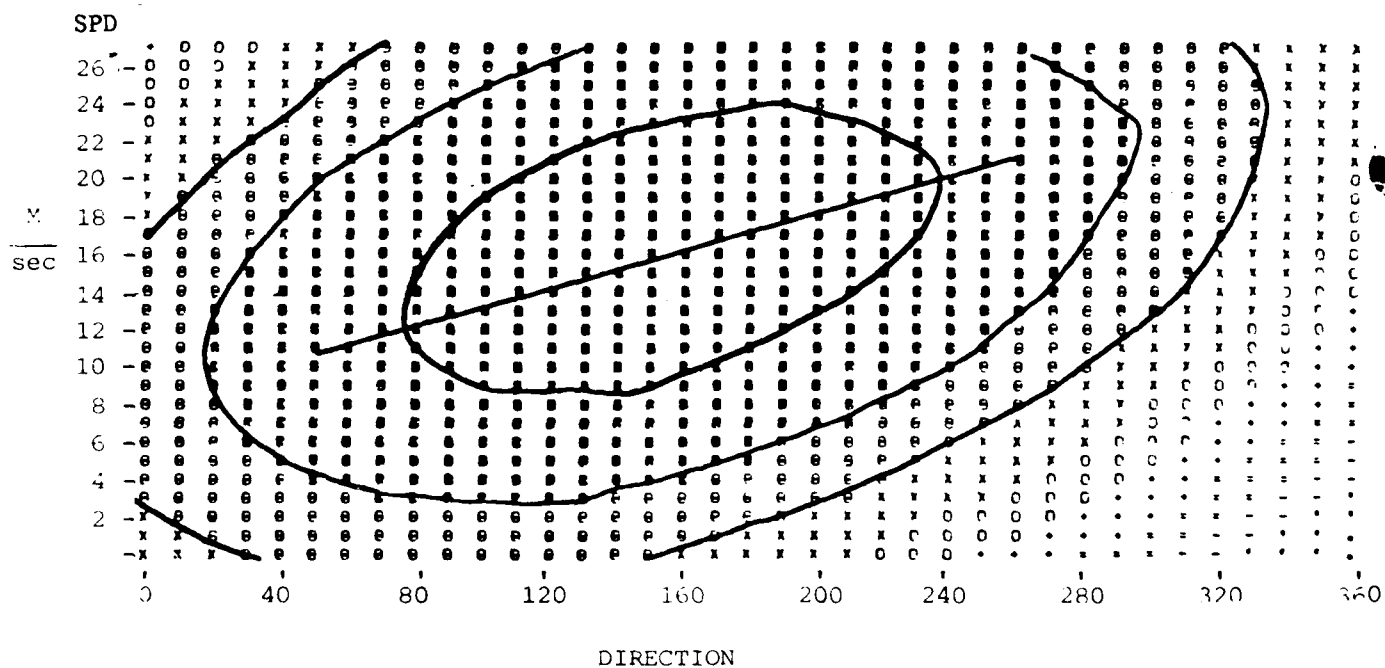
Statistical Analysis was done on the data. Cross variable correlation was observed in the scatterplot for wind speed and wind direction (See figure 12). No other appreciable cross variable correlation was calculated or observed. Table 1 shows the degree to which the variables are cross correlated and serially correlated for Hanover Germany. From the table we can see that there is a strong hourly serial correlation for each of the variables. The variables DIRLAG, SPDLAG, and CLOUDLAG represent the 1 hour lag of the variables wind direction, wind speed, and cloud cover. These high correlation values will be important in modeling as they show the variables do not rapidly change in time. The only significant cross variable correlation shows up between wind speed and wind direction. For Hanover Germany this cross variable correlation (.2968) suggests that a two variable single station simulation model be used.

CORRELATION COEFFICIENTS / NUMBER OF OBSERVATIONS

	Cross Variable			Serial		
	<u>DIR</u>	<u>SPD</u>	<u>CLOUD</u>	<u>DIRLAG</u>	<u>SPDLAG</u>	<u>CLOUDLAG</u>
<u>DIR</u>	1.0000 12447	0.2968 12447	-0.0787 12108	0.8588 12446	0.2959 12446	-0.0734 12107
<u>SPD</u>	0.2968 12447	1.0000 12447	-0.1068 12108	0.2641 12446	0.9055 12446	-0.0969 12107
<u>CLOUD</u>	-0.0787 12108	-0.1068 12108	1.0000 12108	-0.0849 12108	-0.1098 12108	0.5779 11898

Table 1 Shows all correlation values of interest.

PLOT OF WIND SPEED VS WIND DIRECTION (HANOVER)
CONTOUR PLOT OF SPD*DIR



SYMBOL	Z	SYMBOL	Z	SYMBOL	Z	SYMBOL	Z	SYMBOL	Z
.....	13.8 - 16.4	-----	21.7 - 27.0	.....	32.3 - 37.5	XXXXXX	42.8 - 49.1	RRRRRR	53.3 - 58.6
.....	16.4 - 21.7	.....	27.0 - 32.3	000000	37.5 - 42.8	RRRRRR	49.1 - 53.3	RRRRRR	58.6 - 61.2

Figure 12. Scatterplot.

CONCLUSION

From the results of the feasibility study a project to model wind speed, wind direction, and cloud cover is viable. The best way to approach the problem is to simulate wind speed and wind direction together and simulate cloud cover separately. In order to calculate a Pasquill Stability Index we need values for wind speed, time of day, time of year, and cloud cover. Pasquill Stability Indices would be calculated by incorporating simulated data according to Pasquill's chart, as shown in table II (Pasquill 1961, *The Meteorological Magazine*, February 1961).

Surface wind speed (m/s)	Day Insolation			Night	
	Strong	Moderate	Slight	Thinly overcast or $\geq 4/8$ low cloud	$\leq 3/8$ cloud
<2	A	A-B	B	-	-
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

TABLE 2 Strong insolation corresponds to sunny midday summer, slight insolation to similar conditions in midwinter. Night refers to the period 1 hour prior to sunset and 1 hour after dawn. Cloud cover is not as much of a factor in daytime as is insolation (sun angle).

Some assumptions which will have to be made using a two variable single station simulation model are that wind speed and wind direction are correlated to each other, but not correlated to cloud cover. From the preliminary data investigations I have done on several Germany stations this appears to be true. A proposed simulation model will use a first order Markov process called the Ornstein-Uhlenbeck equation and a sawtooth wave submodel to generate the synthetic observations. The model will preserve the unconditional probabilities of occurrence of wind speed and wind direction as well as maintain the desired temporal, spatial, and cross variable correlations. The wind speed/wind direction simulation model will be tuned to a particular geographic area by inputting modeling coefficients and correlation parameters specifically determined from observed weather data for that area. This model would be patterned after an off-the-shelf ceiling/visibility simulator. Another simulator would have to be run to model cloud cover but this would be simpler as it would deal with only one variable. Cloud cover could be modeled using Monte Carlo techniques.

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