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This study evaluates statistical data for two or more meteorological parameters, recorded concurrently, to improve prediction of atmospheric conditions that would obscure a winter battlefield. The analysis considers only freezing precipitation types that were categorized and correlated with simultaneously observed weather conditions, such as temperature, humidity and visibility, using 11 years of winter weather records for Munchen/Riem, Federal Republic of Germany. These results are an example of the unusual and essential environmental

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20. Abstract (cont'd)

information that can be derived from available records. It is suggested that similar investigations should be conducted for other sites in central Europe.

Special Report 84-32

November 1984

US Army Corps of Engineers

Cold Regions Research & Engineering Laboratory

Frozen precipitation and concurrent weather

A case study for Munchen/Riem, West Germany

Michael A. Bilello

Prepared for
OFFICE OF THE CHIEF OF ENGINEERS
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PREFACE

This report was prepared by Michael A. Bilello, Meteorologist, formerly of the Geophysical Sciences Branch, Research Divsion, U.S. Army Cold Regions Research and Engineering Laboratory. The work was performed under DA Project 4A762730AT42-B-E1-5, Winter Battlefield Climatology.

The basic climatological data used in the investigation were obtained through the U.S. Army Atmospheric Sciences Laboratory (ASL), White Sands Missile Range, New Mexico. Pat Avara of ASL prepared the computer programs and provided the output used in this analysis.

This investigation was performed under the guidance and supervision of George Aitken, Program Manager, and Dr. George Ashton, Chief, Geophysical Sciences Branch. The author thanks Dr. Anthony Gow and David Minsk of CRREL for their technical review of the report. The valuable contributions to this study by Mark Hardenberg, for his professional editorial review of the text, by Nancy Richardson and Barbara Gaudette, for the typing and preparation of the report, and by Matthew Pacillo, for drafting the figures, are appreciated. The author acknowledges Nathan Mulherin for assisting in data analysis.

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FROZEN PRECIPITATION AND CONCURRENT WEATHER: A CASE STUDY FOR MUNCHEN/RIEM, WEST GERMANY

Michael Bilello

INTRODUCTION

An important climatological study seldom conducted, and therefore generally lacking in the literature, is the investigation of two or more atmospheric parameters that coincide. In most readily available climatic publications, each weather element is evaluated separately, and the summaries generally provide monthly or annual averages and occasionally maximum and minimum or extreme values. The resulting statistics consequently fail to answer detailed questions, such as, can one expect freezing rain or freezing drizzle more frequently during the night than during midday, and what would the probable range in air temperature be at the time of freezing precipitation? An investigation in which different types of winter precipitation were correlated with other concurrently observed meteorological parameters would be useful. Such results could have a variety of uses, ranging from aiding in the design and construction of roads, runways and buildings to solving the problems associated with the atmospheric effects on electro-optical weapons systems.

In this study, various forms of winter precipitation observed at Munchen/Riem, Federal Republic of Germany, were examined in combination with other concurrently observed weather elements. This site was selected in part because of the strategic military significance of West Germany (de Borchgrave 1977). The NATO armies and the U.S. troops stationed in West Germany often conduct field maneuvers and test new tactics and equipment (Middleton 1976, Larsen 1976); weather is a primary factor affecting the accuracy and reliability of modern weapons. Holt (1980) emphasized the connection between weather and military operations in the following statement:

> ... the development of high technology weapons has resulted in a sensitivity to special properties of the atmosphere over and beyond those commonly associated with the weather. The orderly development of weapons systems with such sensitivities logically re-

quires the prior evaluation of atmospheric effects followed by designs which minimize these effects. To the extent that "weather" in this specialized sense cannot be completely eliminated as a factor in systems performance, it is also important to develop the capability to predict the occurrence of limiting atmospheric conditions, so that the operational employment of sensitive systems will be made with maximum effectiveness.

This report statistically analyzes the atmospheric conditions observed during the winter at the test station. The frozen precipitation types are separated into specific categories and then examined further with respect to key simultaneously observed weather conditions such as temperature, humidity and visibility. Selection of these particular meteorological parameters was based on responses to a questionnaire that was sent to a number of Department of Defense agencies that were interested in the investigation. Key individuals at these agencies reviewed the results of a preliminary analysis of the initial data base and provided suggestions that were used in the final study. Examples of various graphs and tables of the statistical results are given and compared. This detailed study of the winter weather at a selected location is presented as an example of research that could be accomplished from available records, and is designed to be applicable to the battlefield obscuration program.

PREVIOUS STUDIES

A survey of pertinent literature in the following four categories was conducted:

1. Reports on snowfall and snow-cover conditions in Germany
2. Reports on freezing precipitation
3. Reports that discussed the combination of two or more meteorological parameters
4. Reports by the Department of Defense on atmospheric or climatic investigations pertinent to the battlefield obscuration program.

Snow conditions in Germany

This author conducted an earlier historical literature review on snowfall and snow-cover conditions in a study of the mid-winter temperature regime and snow occurrence in Germany (Bilello 1978). Over 110 articles are cited in the text, of which about half are specific studies on snowfall or snow-cover conditions in Germany.

Freezing precipitation

Comprehensive listings of pertinent reports on winter weather, including studies on freezing precipitation, are also available in three reports previously published by this author. The first paper (Bilello 1971) is about frozen precipitation and associated temperatures, and it contains 15 relevant references. The second paper is a bibliography of selected reports on cold regions climatology compiled at CRREL (Bilello and Bates 1972). The third study (Bilello 1974) examines the physical, meteorological and climatological aspects of freezing precipitation in central Alaska. Frequency and duration of inclement weather are evaluated, and concurrent measurements of temperature, wind, atmospheric pressure and visibility are made.

Combined meteorological parameters

Only a few investigators have conducted statistical studies of the simultaneous occurrence of two or more meteorological parameters. Studies that provide such results have been done by Crandall (1977), Keele (1979), Walker and Winn (1980), Miers (1981), and Avara and Monahan (1981). Brief summaries of these five studies are given in Appendix A.

Department of Defense literature

A number of reports on climate, weather and other related environmental factors in Europe have been published. The principal U.S. Government installations where these particular investigations have been conducted are the U.S. Army Electronics Research and Development Command, Atmospheric Sciences Laboratory (ASL), White Sands Missile Range, New Mexico, and the U.S. Air Force Air Weather Service, Scott Air Force Base, Illinois.

Several U.S. Army Regulations (AR), and Military Standards (MIL-STD) provide specific information on climatic parameters such as temperature, relative humidity, radiation and wind speed, with their appropriate limitations. Specific information on winter precipitation in these documents, however, are lacking. For example, for information on snow, AR 705-15 (Department of the Army 1963) provides the range in crystal sizes of falling, blowing or drifting snow under various wind and temperature conditions, and values of snow-load limits and icing accumulation tolerances for equipment. MIL-STD 210B (Department of Defense 1973) provides limited data on snowfall rates and snow crystal sizes, mass flux of snow particles at different heights during periods of blowing snow, and limitations on icing accumulation with respect to thickness and specific gravity. A synopsis of background material for MIL-

STD-210B was prepared by Sissenwine and Cormier (1974), who present additional details on blowing snow conditions, snowfall and snowload values, and ice accretion criteria.

A series of recent winter field experiments also provides new and essential information on the physical characteristics of falling snow and other aspects of the atmosphere, and evaluates their effect on Electro-Optical (E/O) systems (U.S. Army Corps of Engineers 1982, U.S. Army Corps of Engineers 1983). That program investigates the links between equipment performance and specific properties of the atmosphere. Turner (1980) also addresses this important issue.

Appendix A provides an annotated bibliography of other reports by various Department of Defense entities that concern the battlefield obscuration program.

Summary

The preceding literature review was conducted to determine what research had been previously conducted on freezing precipitation in central Europe, and to review the various DOD climatic studies. These probes provided the assurance that the statistical approaches to the meteorological data used in this report would not be a duplication of effort, and that essential environmental information applicable to the battlefield obscuration program would be provided.

ATMOSPHERIC PARAMETERS, DATA SOURCE AND DATA REDUCTION

The hourly weather observations used in this study were recorded at the Munchen/Riem Weather Central, Federal Republic of Germany, located at latitude 40°09' N and longitude 11°43' E. The records from this source were initially retrieved and stored on tapes at the U.S. Air Force Environmental Technical Applications Center (ETAC). These data tapes (and other such climatic records) are made available to all Department of Defense agencies. A request therefore was made to the U.S. Army ASL to obtain the records from 1 January 1966 through 31 December 1976 and to statistically analyze specific types of winter weather and concurrent meteorological parameters. This particular period of record was selected because it had become established as the standard climatic record to be used for any studies associated with the battlefield obscuration program. The results obtained from other environmental investigations could then be compared.

Precipitation types and descriptions

Included in the 99 different present weather codes currently in use by U.S. weather observers are 39 categories that describe different types of freezing precipitation and 14 that define various forms of fog or ground fog. Since it has been strongly stressed that the type of aerosol in the atmosphere is a vital element in the performance of E-O sensors, it becomes apparent that a further breakdown of the reported types of falling hydrometeors in winter would be beneficial. Consequently, the 39 freezing weather codes were divided into 5 general groups and the 14 fog codes were considered as 1 group, but the reported fog observations were separated into 5 consecutive 5°C intervals of concurrent observed air temperature ($5°C \geq T > 0°C$; $0°C \geq T > -5°C$; $-5°C \geq T > -10°C$; $-10°C \geq T > -15°C$; $-15°C \geq T$).

The five general groups of freezing precipitation that were selected are 1) snow-snow showers, 2) freezing rain-freezing drizzle, 3) an assortment of freezing hydrometeors (e.g., ice pellets, snow grains, ice needles, etc.), 4) blowing-drifting snow, and 5) rain and snow mixed. A brief description of some of the above types of weather, based on Huschke (1980), follows.

Snow - Precipitation composed of white or translucent ice crystals, chiefly in complex branched hexagonal form and often agglomerated into snowflakes.

Freezing rain - Rain that falls in liquid form but freezes upon impact to form a coating of glaze ice upon the ground and on exposed objects. While the temperature of the ground surface and glazed objects initially must be at or below freezing, it is also necessary that the water drops be supercooled before striking.

Ice pellets - A type of precipitation consisting of transparent or translucent pellets of ice, 5 mm or less in diameter. They may be spherical, irregular or (rarely) conical in shape. Ice pellets usually bounce when hitting hard ground, or make a sound upon impact. Ice pellets include two basically different types of precipitation, those that are known in the U.S. as sleet and small hail.

Snow grains - Precipitation in the form of very small, white, opaque particles of ice. They resemble snow pellets in external appearance, but are more flattened and elongated, and generally have diameters of less than 1 mm. They neither shatter nor bounce when they hit a hard surface.

Ice needles - A long, thin ice crystal whose cross section perpendicular to its long dimension is typically hexagonal. They are usually observed to form by sublimation at temperatures of -15° to -20°C.

Blowing snow - Snow lifted from the surface of the earth by the wind to a height of 2 m or more (higher than drifting snow), and blown about in such quantities that horizontal visibility is restricted at and above that height.

Fog - A hydrometeor consisting of a visible aggregate of minute water droplets suspended in the atmosphere near the earth's surface. Fog is distinguished from haze by its appreciable dampness and gray color. Mist may be considered as intermediate between fog and haze; its particles are microscopic, it is not as damp as fog, and it does not restrict visibility to the same extent. There is no distinct line, however, between any of the three categories of fog. Near industrial areas, fog often is mixed with smoke, and this combination is known as smog. Finally, according to the U.S. weather observing practice, fog that hides less than six tenths of the sky is called ground fog.

Concurrently observed meteorological phenomena

As stated earlier the main objective of this study was to investigate the occurrence of adverse weather conditions in combination with other concurrent meteorological parameters. Selection of the more important parameters would mostly depend on the needs of the potential users or the operational requirements of present and future E-O sensor equipment. The pertinent phenomena initially selected were concurrent meteorological measurements of air temperature, relative humidity, vapor pressure and visibility.

Upon completion of the preliminary results of the analysis of the basic meteorological data, a questionnaire was sent out to 21 potential users who had expressed an interest in the study (Appendix B). Based on the suggestions received from the responders to the questionnaire, some slight changes were made to the original list of concurrently observed meteorological parameters in the basic data. Namely, retain air temperature, relative humidity and visibility; omit vapor pressure; and add absolute humidity, wind speed, cloud height and the Pasquill stability index.*

*A definition of the Pasquill stability index and its derivation source are given by Avara and Monahan (1981).

Table 1. Sample list of hourly observations containing selected winter weather groups and their weather codes (C-1 through C-11) and selected concurrently observed meteorological parameters.

LISTING OF HOURLY OBSERVATIONS CONTAINING PERTINENT PRESENT WEATHER FOR MUNCHEN/RIEM, FRG

PERTINENT PRESENT WEATHER CLASSES ARE---

C-1 (SNOW AND SNOW SHOWERS) - WW CODES 22,26,70-75,85-86,93-94.
C-2 (FREEZING RAIN/DRIZZLE) - WW CODES 24,56-57,66-67.
C-3 (OTHER FREEZING PRECIP.) - WW CODES 27,76-79,87-90,96,99.
C-4 (FOG AND GROUND FOG) - WW CODES 10-12,28,40-49.
C-5 (BLOWING SNOW) - WW CODES 36-39.
C-6 (RAIN AND SNOW MIXED) - WW CODES 23,68-69,83-84,97.
C-7 (FOG AND GROUND FOG WITH TEMP LE -15 C)
C-8 (FOG AND GROUND FOG WITH -15 LT TEMP LE -10 C)
C-9 (FOG AND GROUND FOG WITH -10 LT TEMP LE -5 C)
C-10 (FOG AND GROUND FOG WITH -5 LT TEMP LE 0 C)
C-11 (FOG AND GROUND FOG WITH 0 LT TEMP LE 5 C)

TEMPERATURES ARE IN DEGREES CELSIUS, RELATIVE HUMIDITIES ARE IN PERCENT, ABSOLUTE HUMIDITIES VISIBILITIES ARE IN KMS, WIND SPEEDS ARE IN MPS, AND CEILING HEIGHTS ARE IN METERS.

YEAR	MONTH	DAY	HOUR	MINUTE	TEMP.	REL.HUM.	ABS.HUM.	VISBY.	WND.SPD.	CEIL.HT.	PASQL.	WW CODES
66	1	4	12	0	-.0	86.32	4.18	.000	9.2	240.0	4.	86
66	1	8	21	0	-7.0	92.53	2.72	1.800	1.0	.0	6.	11
66	1	9	0	0	-9.0	100.00	2.53	1.700	1.0	.0	6.	11
66	1	10	0	0	-6.0	92.59	2.93	2.000	1.0	600.0	4.	73
66	1	10	3	0	-6.0	85.67	2.71	2.000	1.5	150.0	4.	73
66	1	11	12	0	-8.0	85.44	2.33	2.000	4.1	300.0	4.	71
66	1	11	15	0	-8.0	85.44	2.33	1.600	5.1	390.0	4.	73
66	1	11	18	0	-8.0	85.44	2.33	1.800	4.1	300.0	4.	71
66	1	11	21	0	-8.0	85.44	2.33	2.000	5.1	300.0	4.	71
66	1	12	0	0	-9.0	92.40	2.34	2.000	5.1	450.0	4.	73
66	1	12	15	0	-8.0	85.44	2.33	1.700	4.1	270.0	4.	71
66	1	12	21	0	-10.0	92.34	2.17	2.000	2.0	600.0	4.	71
66	1	13	3	0	-10.0	92.34	2.17	2.000	3.0	300.0	4.	73
66	1	13	9	0	-9.0	92.40	2.34	1.600	2.5	720.0	4.	71
66	1	13	21	0	-9.0	92.40	2.34	2.000	5.1	600.0	4.	73
66	1	16	3	0	-12.0	84.97	1.71	2.000	2.0	60.0	4.	71
66	1	16	6	0	-13.0	92.15	1.72	2.000	2.0	100.0	4.	22
66	1	16	18	0	-15.0	92.02	1.47	.400	1.0	.0	6.	46
66	1	17	3	0	-17.0	91.88	1.25	1.800	1.0	60.0	4.	78
66	1	17	9	0	-14.0	92.08	1.59	2.000	1.0	150.0	3.	78
66	1	17	18	0	-16.0	91.95	1.36	1.600	1.5	.0	6.	11
66	1	17	21	0	-17.0	91.88	1.25	1.600	1.0	270.0	6.	11
66	1	18	0	0	-15.0	92.02	1.47	2.000	1.0	330.0	4.	71
66	1	18	6	0	-14.0	92.08	1.59	2.000	1.5	390.0	4.	71
66	1	18	9	0	-13.0	84.85	1.59	1.800	1.0	480.0	4.	71
66	1	18	21	0	-12.0	84.97	1.71	2.000	2.5	600.0	5.	71
66	1	19	9	0	-13.0	84.85	1.59	1.600	1.0	450.0	4.	71
66	1	19	12	0	-11.0	72.20	1.57	2.000	1.5	.0	2.	22
66	1	19	18	0	-13.0	92.15	1.72	2.000	1.0	.0	6.	11
66	1	19	21	0	-11.0	92.28	2.01	2.000	2.5	.0	6.	41
66	1	20	0	0	-15.0	92.02	1.47	2.000	2.0	.0	6.	41
66	1	20	6	0	-18.0	100.00	1.26	.000	1.0	30.0	4.	49,
66	1	20	9	0	-17.0	91.88	1.25	1.600	.0	.0	3.	10
66	1	21	9	0	-11.0	85.09	1.85	1.300	1.0	.0	3.	40
66	1	21	18	0	-6.0	85.67	2.71	2.000	1.5	900.0	4.	10
66	1	22	0	0	-3.0	92.77	3.64	.300	1.0	1500.0	4.	46

Table 1 is an example of a computer print-out of the basic hourly weather data for Munchen/Riem (present weather code numbers (WW) are also shown). This is the first page of the listing for the entire period of record (1 January 1966 through 31 December 1976). It should be noted again that the extraction and analysis of these winter weather records for Munchen/Riem is an example; it could also be done for other areas.

Data reduction and computation format

Initially, all reported events for the 11 years of record were statistically analyzed for each hour. However, this time interval proved unrealistic because it often provided erratic results. Two possible reasons for this are a bias inherent in the data base because much of the record has observations every 3 hours and that the selected breakdown of winter weather had too many categories to permit hourly analyses. Consequently, in the revised calculations all events reported during sequential 3-hour intervals for the 11 years of record were used instead.

It is convenient here to point out other suggestions given in response to the Appendix B questionnaire. Some responsers noted, for example, that knowing the probability of an event happening during periods of 10-20 years or estimating the persistence of a particular adverse weather condition would be worthwhile. Unfortunately, because of the limited number of observed events, the relatively short period of record, and omitted or missing records, such analyses would be statistically unsound and consequently were avoided.

Frequency calculation

In view of the preceding discussions, frequency values (in hours per month) were obtained for each of the selected weather groups. These probability values were calculated for each of the sequential 3-hour intervals, and a total value for each month was tabulated. Table 2 is an example of the computer print-out of these frequency values for snow-snow showers. The values were determined by the formula

$$F = \frac{(E)(3)(D)}{H} \qquad (1)$$

where F = frequency (in hours)

E = number of hours an appropriate weather code (for each of the selected groupings) was observed during each of the 3-hour intervals

3 = number of hours in each interval

D = number of days in the month

H = number of hourly observations taken at the weather station for each 3-hour time interval during the entire 11-year record (see Table 3 for sample print-out).

A sample calculation using eq 1 (for snow-snow showers) for observations made at 0000, 0100 and 0200 hours (i.e., 00-02 in Table 2) in January at Munchen/Riem for the 11-year record is

Table 2. Frequency (number of hours per season) of snow-snow showers.

FOR PRESENT WEATHER CLASS C-1

NO. HRS FREQUENCY OF OCCURRENCE OF PRESENT WEATHER FOR MUNCHEN/RIEM, FRG

MONTH	00-02	03-05	06-08	09-11	12-14	15-17	18-20	21-23
	TIME OF DAY (LST)							
JAN	9.87	9.09	10.06	10.29	10.27	8.33	8.71	9.30
FEB	12.18	13.94	13.87	13.69	11.97	9.36	10.26	12.03
MAR	13.62	14.04	12.38	12.31	9.88	9.24	8.56	9.96
APR	4.46	5.09	7.00	7.03	7.15	4.62	3.47	3.52
MAY	.23	.23	.35	.23	.23	.24	.12	.00
JUN	.00	.00	.00	.00	.00	.00	.00	.00
JUL	.00	.00	.00	.00	.12	.00	.00	.00
AUG	.00	.00	.00	.00	.00	.00	.00	.00
SEP	.11	.10	.00	.00	.00	.00	.00	.00
OCT	.50	.61	.51	.61	.31	.61	.51	.72
NOV	5.09	5.65	6.12	6.27	5.51	5.90	5.47	5.14
DEC	12.14	13.63	14.52	13.73	12.29	11.85	10.72	12.82

MONTH	ALL HOURS
JAN	75.93
FEB	97.29
MAR	89.98
APR	42.36
MAY	1.63
JUN	.00
JUL	.12
AUG	.00
SEP	.21
OCT	4.37
NOV	45.14
DEC	101.71

Table 3. Total number of hours of weather observations taken during the 11 years of record.

NUMBER OF HOURLY OBSERVATIONS TAKEN AT MUNCHEN/RIEM, FRG

MONTH	00-02	03-05	06-08	09-11	12-14	15-17	18-20	21-23
	TIME OF DAY (LST)							
JAN	801	808	804	795	797	793	790	800
FEB	738	727	727	718	730	736	737	733
MAR	792	789	804	801	791	785	793	794
APR	766	760	771	781	780	780	777	766
MAY	796	804	802	796	800	785	803	803
JUN	774	764	775	786	730	761	779	782
JUL	745	734	747	765	759	754	748	746
AUG	804	796	808	796	804	798	820	815
SEP	850	850	865	867	866	854	867	852
OCT	924	916	916	922	911	912	915	909
NOV	901	892	897	876	882	885	889	876
DEC	919	921	922	921	908	926	911	907

$$F = \frac{(85)(3)(31)}{801} = 9.87 \quad (2)$$

This value (9.87) means that from 0000, to 0259 hours (local time) in January, snow-snow showers were observed an average of 9.87 hours. When the values for all of the 3-hour intervals for the month are combined, the frequency of snow-snow showers for January is 75.93 hours, or about 10.2% of the time

$$\frac{75.93 \text{ (expected hours)}}{24 \text{ (hours) } 31 \text{ (days)}} = 10.2\% . \quad (3)$$

Although percentage of time probabilities at first were considered useful, they were later not included in the study -- reasons for this decision are given in the Monthly Frequency section.

One of the suggestions given in the reviews of the preliminary results of this investigation was that because researchers are usually interested in numerical tabulations from which graphs are derived, these tables should be readily available. Table 2 showing snow-snow showers is a good example. Similar tabulations were provided for the other selected weather groups used in this study but to avoid excessive bulk they were not included here. However, the same data bank and computer service used in this study are available for other similar studies.

Concurrent weather conditions

As noted earlier, the major purpose of this report was to correlate key atmospheric conditions with the simultaneously observed winter weather events. The concurrent meteorological parameters finally selected were air temperature (°C), relative humidity (%), absolute humidity (g/m^3), visibility (km), wind speed (m/s), cloud ceiling heights (m) and Pasquill stability index. By use of the data base given in the hourly observation tabulations (e.g., see Table 1), the arithmetic means and standard deviations of these concurrently observed atmospheric parameters were calculated. These means and 1-sigma standard deviations* for each of the meteorological parameters were determined by appropriate calculations (e.g., see Brooks and Carruthers 1953), using the same sequential daily 3-hour intervals used in the frequency calculations. A sample tabulation of these means and standard deviations for air temperature observed during the 3-hour intervals of snow-snow showers is shown in Table 4. According to Table 4, for example, one can expect mean air temperatures of between -1.6 and -4.0°C during snow-snow showers in December and January at Munchen/Riem. However, the standard deviations indicate that these temperatures could vary from ±5.8 to ±8.9°C in about 68% of the cases. Further discussion of such variations as well as several graphical interpretations of some interesting aspects of the winter weather are given in the next section.

*Reviewers of the preliminary results of this study suggested that 2-sigma standard deviations would be more useful. If and when this is the case, the standard deviation values given in this study need simply be doubled.

Table 4. Air temperatures observed during snow-snow showers (based on the 11-year record).

FOR PRESENT WEATHER CLASS C-1

MEAN TEMPERATURE FOR MUNCHEN/RIEM, FRG DURING YEAR

MONTH	00-02	03-05	06-08	09-11	12-14	15-17	18-20	21-23
	TIME OF DAY (LST)							
JAN	-3.79	-3.51	-3.95	-3.41	-2.01	-1.60	-2.78	-3.63
FEB	-1.83	-1.33	-1.76	-1.72	-.89	-.96	-1.35	-1.73
MAR	-2.22	-2.42	-2.55	-1.30	-.40	-.38	-.66	-1.60
APR	.42	-.19	-.00	.70	1.53	1.80	.80	.37
MAY	1.00	1.00	4.33	3.00	1.50	1.50	3.00	.00
JUN	.00	.00	.00	.00	.00	.00	.00	.00
JUL	.00	.00	.00	.00	13.00	.00	.00	.00
AUG	.00	.00	.00	.00	.00	.00	.00	.00
SEP	17.00	14.00	.00	.00	.00	.00	.00	.00
OCT	.60	1.33	.40	1.50	1.67	2.67	1.20	1.14
NOV	-.39	-.54	-.79	-.47	-.22	-.65	-.71	-.46
DEC	-3.23	-2.82	-2.51	-2.91	-1.95	-2.19	-2.07	-2.88

ST DEV TEMPERATURE FOR MUNCHEN/RIEM, FRG DURING YEAR

MONTH	00-02	03-05	06-08	09-11	12-14	15-17	18-20	21-23
	TIME OF DAY (LST)							
JAN	8.59	8.22	8.94	8.86	7.04	5.85	6.48	8.37
FEB	5.34	4.63	5.18	5.48	5.46	5.11	4.71	5.33
MAR	7.80	6.46	6.58	5.64	5.39	6.08	5.16	6.16
APR	3.63	2.03	3.10	2.69	3.06	3.85	2.75	2.28
MAY	.00	.00	3.06	.00	1.00	1.00	.00	.00
JUN	.00	.00	.00	.00	.00	.00	.00	.00
JUL	.00	.00	.00	.00	.00	.00	.00	.00
AUG	.00	.00	.00	.00	.00	.00	.00	.00
SEP	.00	.00	.00	.00	.00	.00	.00	.00
OCT	1.60	1.49	1.60	1.00	2.49	1.89	.00	.00
NOV	3.07	3.34	3.99	3.65	4.64	3.64	.80	2.49
DEC	7.14	6.31	6.69	7.05	5.86	6.53	3.29	3.38

GRAPHING THE DATA

The tabulated data and statistical analyses of them can be graphically presented in several ways. Determination of the best method depends upon how and by whom the information will be used. Typical questions that arise are: 1) What time periods should be used? That is, should the data be broken down into monthly, daily or hourly distributions? 2) What combinations of the numerous variables should be shown, and when would tables be preferable to graphics? 3) For planning, operations or forecasting, would information on the frequency of extremely poor weather be useful? If so, what atmospheric limits should be used to define such adverse conditions?

Based on previous surveys of frozen precipitation (Bilello 1971, 1974) and suggestions received from the questionnaire, the data for Munchen/Reim were interpreted in several graphs and tables. All of the winter precipitation groups and meteorological parameters selected for this study are included in the sample diagrams or tables. This exercise attempts to produce detailed information on critical aspects of the natural environment during the cold months of the year.

Monthly frequency

In the preliminary analysis of the basic data (Appendix B), the monthly frequency values for each of the general weather groups were expressed in percentage of the time (e.g., Fig. B1). This interpretation of the data is not entirely valid because it implies that the reported weather continued throughout the hour in which it was observed. Actually, it often may not have lasted for the full 60 minutes of the hour. It was decided, therefore, to express the frequency in number of reported hours as determined by eq 1 and as given in the computer tabulations (Table 2). The understanding in this case is that the particular weather occurred at the time the observation was made during the recorded hour. Bar graphs, similar to those given in the preliminary analysis, were used again because they provide a compact display of monthly frequencies and a comparison of these values between the weather groups (Fig. 1). Note that only the fogs with concurrent air temperatures of equal to or less than 0°C (i.e., classes C-7 through C-10, see Table 1) were included in this diagram. The majority of the fog-ground fog at temperatures between 5° and 0°C occurred during the autumn and spring. These therefore were omitted from the seasonal distribution of winter fogs shown in Figure 1.

The monthly frequency values presented in Figure 1 show that snow-snow showers and fog-ground fog are the most prevalent forms of adverse winter weather observed at Munchen/Riem. The distribution reveals a peak during December, and that one can expect snow and fog from November through March and part of April. Instances of freezing rain-freezing drizzle, rain and snow mixed, and other forms of frozen precipitation (ice pellets, granular snow, etc.) at this location are relatively infrequent. Blowing-drifting snow also occurred too few times during the 11-year record to be included in Figure 1. However, it should be stressed that both freezing rain-freezing drizzle and blowing and drifting snow can sometimes persist continuously for extended periods.

For example, an examination of the hourly print-out of the 11 years of record used in this study revealed two lengthy freezing rain-freezing drizzle storms. One began at about 2000 hours on 9 December 1968 and ended the following day at 1000 hours; the second ran from 2000 on 8 January 1973 to 0700 on the next day. Similarly, there was an extended period of blowing-drifting

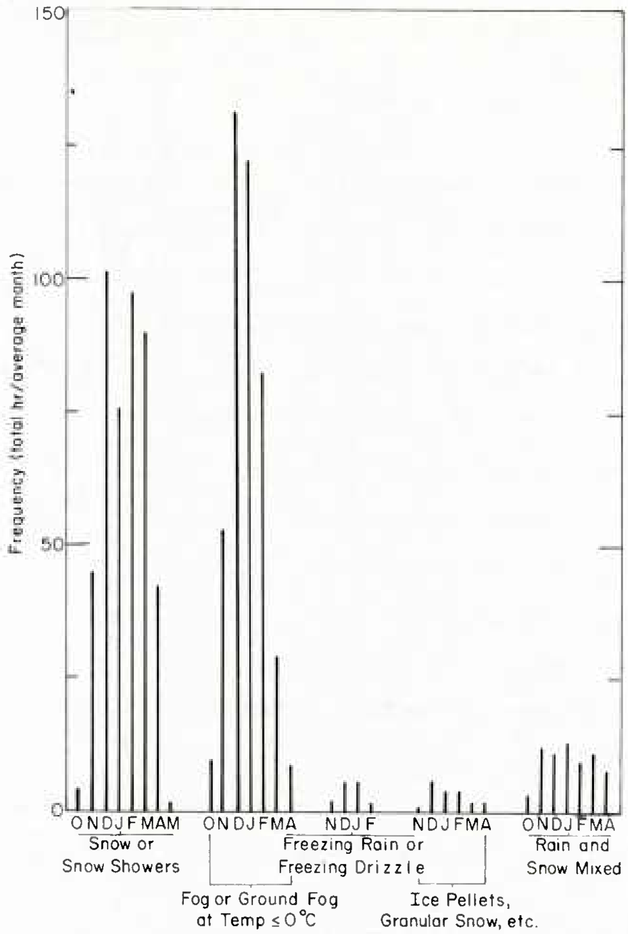


Figure 1. Monthly frequency distribution of various forms of freezing weather. Values are averages based on the 11-year record.

snow at this station between 1800 on 27 November 1973 and 1300 on the following day, when these conditions were reported during 10 hours. Obviously, monthly frequencies for such conditions would not be useful. However, if statistics on the number and duration of these type of storms are required, a computer scan of the hourly observations (as shown later for blowing-drifting snow) could be conducted to extract such information. But, in order to make the survey representative, the period when information was collected should be reasonably long and without gaps.

Frequency for 3-hour periods

For planning and operations, knowledge of when to expect adverse weather throughout the day would be useful. The computer listings (e.g., see Table 2) of the frequency values for 3-hour intervals can provide this information.

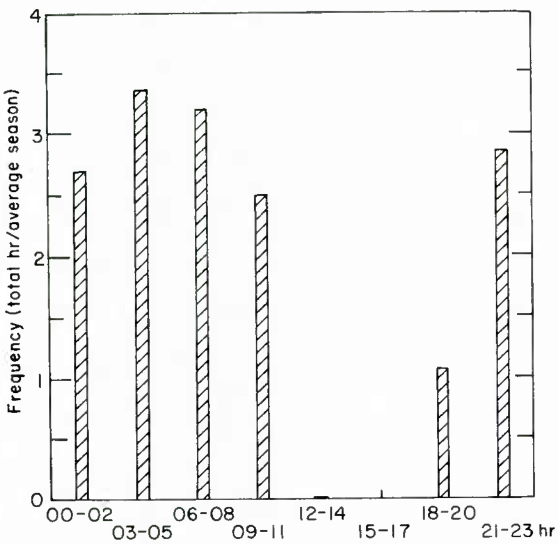


Figure 2. Diurnal frequency distribution of freezing rain-freezing drizzle. Values are averages based on the 11-year record.

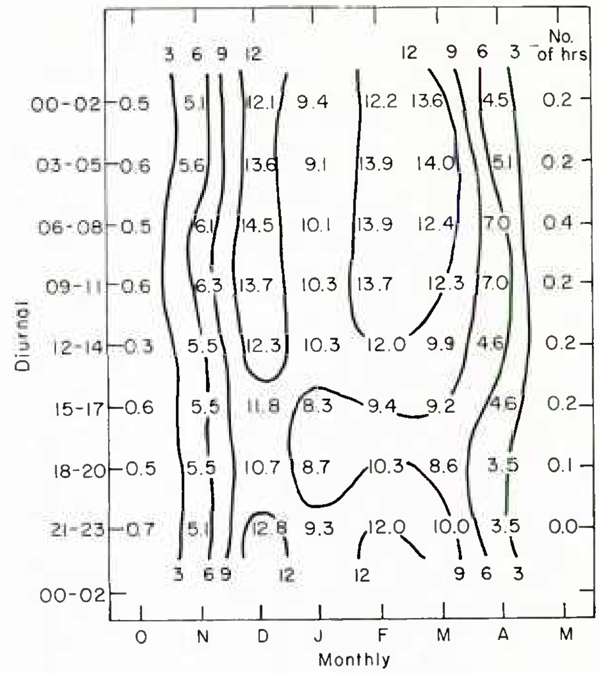


Figure 3. Diurnal frequency distribution of monthly totals for snow-snow showers (total hours/average season). Values are averages based on the 11-year record.

Graphically, this diurnal frequency distribution could be shown in two ways, either with all of the expected frequency values determined for each of the 3-hour intervals combined as a seasonal total, or with each 3-hour interval frequency value shown separately for each month of the season.

If freezing rain-freezing drizzle is used as an example, and since it occurs infrequently, the first type of graph would be more suitable. Figure 2 shows the frequency distribution of freezing rain or freezing drizzle that can be expected per winter throughout the day. The graph clearly shows that freezing rain or freezing drizzle hardly ever occurs between 1200 and 1700 hours at Munchen/Riem. As noted in the text of Appendix B, this diurnal phenomenon has also been observed in the central United States. Since the concurrent air temperatures during this weather event are generally between approximately -3.3° and 0°C (Bilello 1971), this mid-day reduction may be partially attributed to the diurnal heating of the lower atmosphere during those hours.

Since it snows frequently, the second type of graph, in which the 3-hourly frequency values are also shown separately by month, could be used (Fig. 3). The monthly distribution peaks in December, February and March, and the diurnal distribution reveals a slight decrease between 1500 and 2000 hours. Knowledge of the probable time of day that adverse weather is likely to improve would be essential to the military.

Graphs of concurrent meteorological parameters

Because six basic winter weather groups and seven different concurrent meteorological parameters were identified for this study, it would be impractical to graph all possible combinations of these variables. The necessary data, however, to make any desired combination of the variables are available in computer files at ASL. A few graphs of some interesting combinations will instead be given here as examples.

Previous graphs

Four graphs (Fig. 4 and 5a-c) developed from the preliminary analysis of the basic data were considered useful. These diagrams provide the following combinations of atmospheric conditions for Munchen/Riem: monthly means and standard deviations (1-sigma) of air temperature, relative humidity and visibility observed during snow-snow showers (Fig. 4); distributions by month of mean air temperatures recorded in 3-hour periods during snow-snow showers (Fig. 5a); monthly distributions of mean relative humidity values recorded in 3-hours periods during snow-snow showers (Fig. 5b); and monthly distributions of mean visibilities recorded in 3-hour periods during snow-snow showers (Fig. 5c). Further explanations of these figures are given in the text of Appendix B.

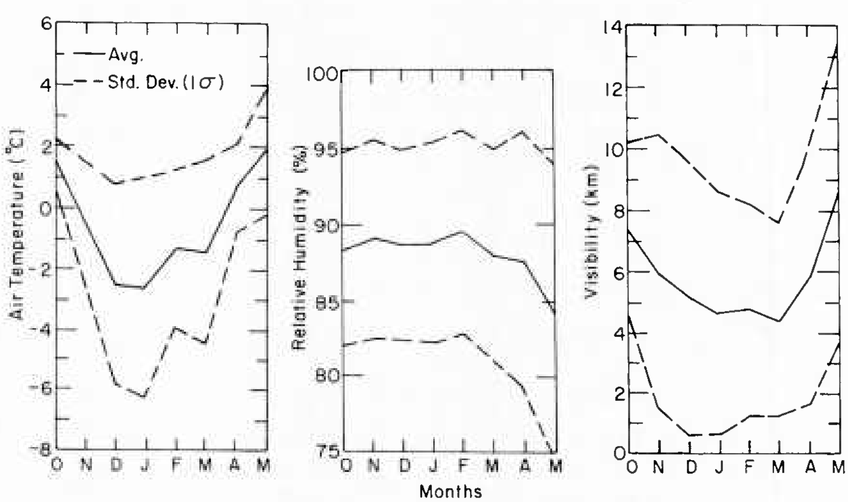
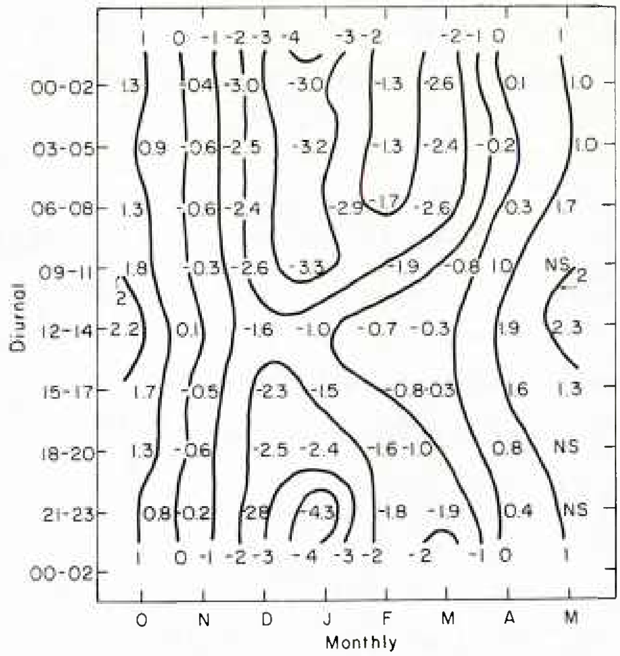
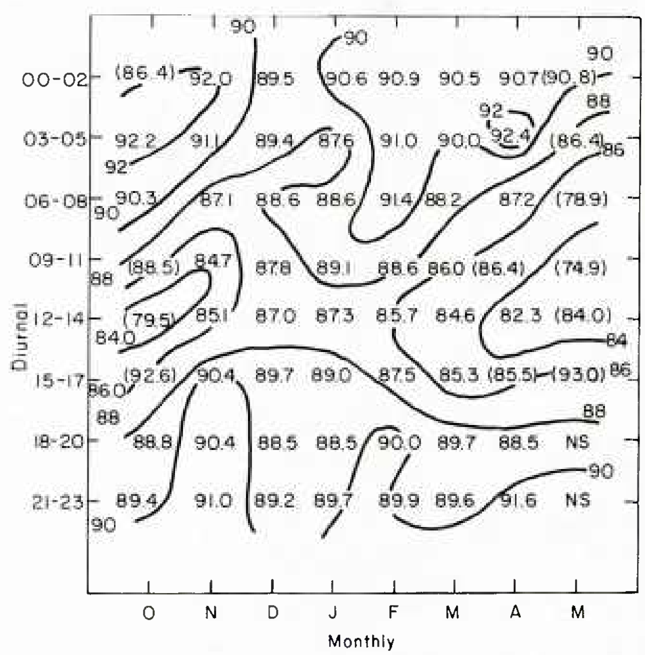


Figure 4. Monthly means and standard deviations of air temperature, relative humidity and visibility recorded during snow-snow showers (based on 11-year record.

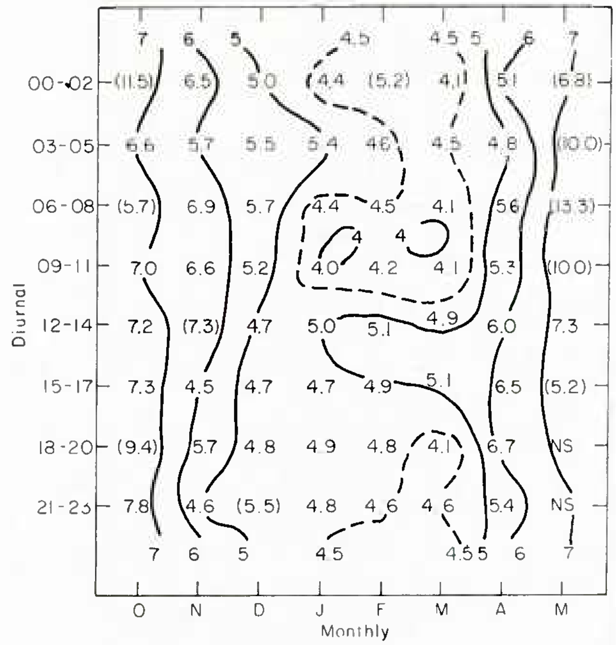


a. Air temperature (°C).



b. Relative humidity (%).

Figure 5. Diurnal frequency distribution of monthly means of air temperature, relative humidity and visibility recorded during snow-snow showers (based on 11-year record). NS - no snow; values in parenthesis are estimated.



c. Visibility (km).

Figure 5 (cont'd).

Additional graphs

Since a number of other concurrently observed atmospheric parameters were added to the study, it would be worthwhile to examine their daily and monthly variations during different forms of winter precipitation. In an attempt to emphasize the potential application of the graphs, each of the following diagrams will be preceded by a question. The questions will probe unique aspects of the winter weather, and ask for information on specific atmospheric conditions that might be expected at certain times and locations.* Today's conventional weather forecasts do not provide the answers to the type of inquiries that are presented here. The decision to employ certain E-O systems, and other equipment sensitive to atmospheric conditions, however, will often depend on specific information about the expected environmental conditions described in this study.

Absolute humidity variations. There was general agreement in the suggestions received through the questionnaire that both relative humidity and absolute humidity values are generally required. It was noted, for example, that relative humidity is used in deriving fog particle size distribu-

*The location in this case would, of course, be at or near Munchen/Riem. It would be of interest to determine, from results of other similar studies, how the values vary from place to place in central Europe.

tions and snowflake characteristics, whereas absolute humidity is used in computing infrared absorption by water vapor. It would be conceivable, therefore, that operators of infrared equipment would ask, Are there differences in the observed values of absolute humidity during snow-snow showers as compared to periods of fog-ground fog at air temperatures of 0° to 5°C? If so, what are these differences, and can one expect diurnal and monthly variations in the values?

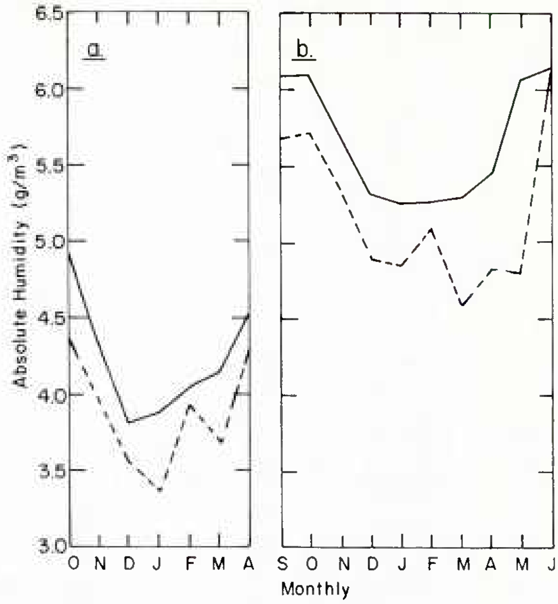


Figure 6. Monthly distribution of the highest (solid line) and lowest absolute humidity values (averages for 3-hour intervals, based on 11-year record) observed during (a) snow-snow showers and (b) fog-ground fog at temperatures of 0° to 5°C.

The results shown in Figure 6 provide the answers. The monthly highest and lowest (averages for 3-hour periods) observed absolute humidity values were significantly higher during periods of fog-ground fog (at 0° to 5°C) than during snow-snow showers. All of the absolute humidity values shown for fog-ground fog were greater than 4.55 g/m^3, whereas all those shown for snow-snow showers (except for one value in October) were less than 4.55 g/m^3. Figure 6 also reveals the quantitative values of the midwinter reduction in absolute humidity during both fog-ground fog and snow-snow showers.

The data were further examined to determine the time of day of these highest and lowest values. For fog-ground fog, seven of the ten high absolute humidity values were recorded between 2100 and 0500 hours, and eight of the ten low values between 0600 and 1700 hours; for snow-snow showers, six of the seven high values were recorded between 1500 and 2400 hours, and six of the low values between 0600 and 1400 hours. These distributions are closely associated with the usual diurnal trends in higher and lower air temperatures and the respective decrease and increase in atmospheric moisture content.

Another interesting question regarding variations in absolute humidity in a winter atmosphere would be, What differences in absolute humidity would one expect during fog-ground fog at various ambient air temperatures? A plot

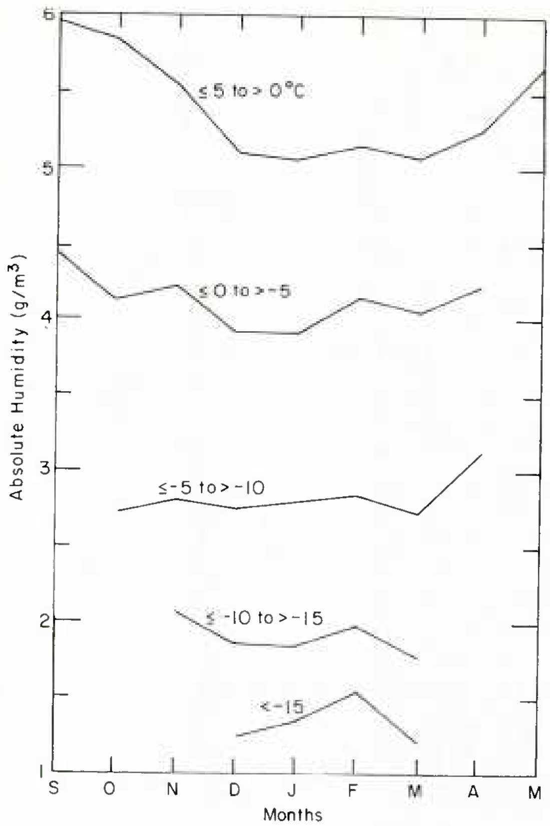


Figure 7. Mean monthly absolute humidity values observed during fog-ground fog at various air temperatures (based on 11-year record).

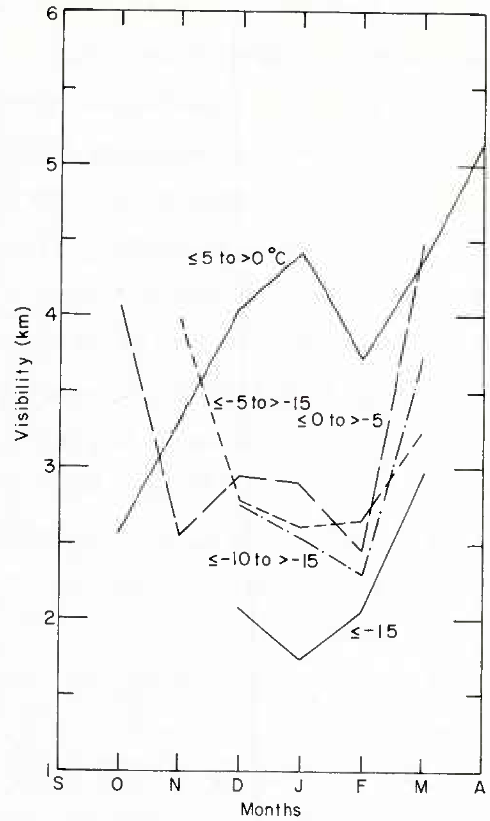


Figure 8. Mean monthly visibility values observed during fog-ground fog at various air temperatures (based on 11-year record).

of the monthly mean values of absolute humidity in fogs recorded during five intervals of concurrent air temperatures ranging from 5° to -15°C is shown in Figure 7. The figure shows that absolute humidities decrease markedly as the air temperature becomes lower during fogs. Note also the slight decrease in absolute humidity observed during the midwinter fogs at temperatures higher than -5°C; this phenomenon is not as marked for fogs at lower temperatures.

Visibility variations. Fog is without doubt the principal cause of reduced visibility in much of central Germany in winter (Duncan and Low 1980, Lindberg 1982). Since it has been shown that absolute humidity varies in response to the ambient air temperature, the next obvious question would be, How does visibility vary during fog-ground fog at different air temperatures?

Figure 8 is a plot of the mean monthly visibility values recorded during five intervals of winter air temperatures ranging from 5° to -15°C. Except for those fogs at temperatures of 5° to 0°C, the mean monthly trends in visibility for the other temperatures are similar. Visibility decreases during October and November, reaches a minimum in January or February and increases sharply in March. These midwinter minimums in visibility, of course, are largely ascribable to reduced daylight.

There was an unexpected anomaly in the mean monthly trends in visibility for fog-ground fog at temperatures between 5° and 0°C. The line in this case showed the lowest mean monthly visibility value of near 2.5 km occurring in October. Visibility (except for February) then generally increased each month to a mean value of over 5.0 km in April. The poorer visibility in October may be a reflection of additional available moisture in the atmosphere (i.e., dense fogs) at this time of year (see Fig. 6). The improvement in visibility through the darker midwinter months during these particular fogs, however, is difficult to explain.

Table 5. Visibility (km) during snow-snow showers.

	Time of day (local time)							
Month	00-02	03-05	06-08	09-11	12-14	15-17	18-20	21-23
				Mean				
Jan	4.36	4.96	4.96	4.13	4.82	5.24	4.14	4.96
Feb	5.36	4.70	4.35	4.23	5.14	5.01	4.77	4.41
Mar	4.41	4.27	4.36	4.12	4.85	4.96	4.36	4.52
Apr	5.83	5.56	5.06	5.64	5.66	6.53	7.25	5.30
May	6.25	9.00	18.67	10.00	5.00	4.20	9.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	--	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	8.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	10.08	7.07	7.64	5.20	2.83	9.07	8.84	7.84
Nov	5.94	5.94	6.61	6.56	7.43	4.28	4.99	4.65
Dec	5.06	5.41	5.61	4.54	4.74	4.65	5.03	5.05
				Standard deviation				
Jan	8.07	8.84	8.50	10.48	11.54	11.79	8.64	6.93
Feb	7.40	6.61	5.87	6.52	8.70	8.65	8.07	7.01
Mar	6.44	6.19	6.92	6.43	9.25	8.28	6.16	6.85
Apr	9.29	8.87	7.97	9.58	8.60	10.77	13.20	7.33
May	7.50	2.00	30.87	0.00	10.00	5.60	0.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	3.45	8.84	7.08	6.81	7.32	7.82	4.36	5.32
Nov	8.83	9.15	12.47	14.15	12.57	7.59	7.10	5.69
Dec	9.29	9.15	11.80	7.81	9.26	7.32	9.46	8.25

In order to emphasize the major variations in visibility that can be expected during snow-snow showers, the calculated monthly means for 3-hour periods and their respective standard deviations are presented in Table 5. Except for the obvious unrepresentative values because of insufficient data in September, October and May, most of the mean visibilities lie between 4 and 7 km. However, a scan of the standard deviations (1-sigma) reveals that major variations in these mean visibilities for 3-hour periods can be expected. Further information on the concentration of falling snow and its relation to visibility is given by Stallabrass (1979).

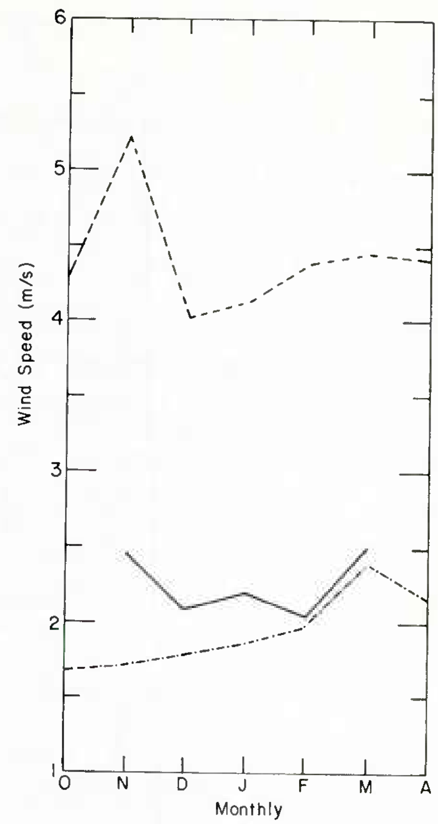


Figure 9. Mean monthly wind speed values observed during snow-snow showers (dashed line), freezing rain-freezing drizzle (solid line), and fog-ground fog (dot-dash line).

Wind speed variations. A few responders to the questionnaire indicated that information on wind speed during periods of inclement weather could be useful in their particular winter battlefield obscuration research. A typical question that would address this subject would be, Do wind speeds differ markedly during various forms of winter weather? The answer, for three different weather classes (snow-snow showers, freezing rain-freezing drizzle and fog-ground fog), between October and April is shown in Figure 9. The mean monthly wind speeds during snow-snow showers range between 4.0 and 5.2 m/s, whereas during periods of freezing rain-freezing drizzle and fog-ground fog the mean monthly wind speeds range between 1.6 and 2.5 m/s. The lesser wind speeds during fog were expected, but the differences in wind speed recorded during snow and freezing rain were unexpected. One wonders whether these particular wind conditions are unique to the Munchen/Riem region.

Except for the probably unrepresentative point obtained during November for snow-snow showers (Fig. 9), the mean monthly wind speed values for all three weather types were generally uniform throughout the winter.

Ceiling height variations. Another extremely variable meteorological condition that questionnaire responders suggested be added to the study was

Table 6. Mean cloud ceilings (m) during snow-snow showers.

Month	Time of day (local time) 00-02	03-05	06-08	09-11	12-14	15-17	18-20	21-23
Jan	464.47	493.85	581.67	955.30	547.32	423.91	417.08	618.03
Feb	742.35	526.13	496.67	654.27	560.40	733.03	862.33	929.41
Mar	659.20	535.38	602.06	535.67	483.46	532.06	755.22	1196.67
Apr	472.50	466.83	547.63	602.07	493.64	941.47	957.24	841.03
May	345.00	270.00	970.00	600.00	750.00	1860.00	900.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	--	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	1200.00	3000.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	1275.00	520.00	558.00	210.00	540.00	498.00	636.00	770.00
Nov	503.12	467.88	798.00	772.91	849.80	465.56	472.50	433.70
Dec	564.87	724.92	1017.13	660.71	920.00	889.29	629.70	799.50

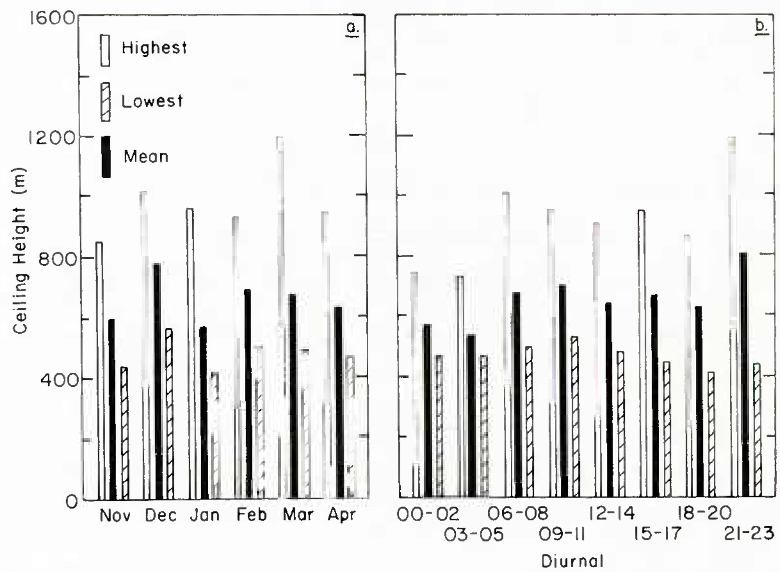


Figure 10. Monthly (a) and diurnal (b) distribution of cloud ceiling heights recorded during snow-snow showers.

the reported ceiling height of the clouds. A scan of the tabulated mean monthly cloud ceilings for 3-hour periods during snow-snow showers from November through April, for example, revealed a low of 417 m and a high of 1197 m (Table 6). The question that arises regarding this range in ceiling height is, What diurnal and monthly variations in cloud ceiling can be expected during periods of snow-snow showers?

These time distributions are shown in a plot of the highest, the lowest and the mean ceiling heights recorded during November through April for snow-snow showers; Figure 10 shows only slight variations in the high, low and

Table 7. Comparison of cloud ceiling heights (m) recorded during mixed rain and snow, and snow-snow showers.

	Mixed rain and snow			Snow-snow showers		
	High*	Mean**	Low*	High*	Mean**	Low*
November	732	538	369	850	595	434
December	1265	698	481	1017	776	565
January	553	410	291	955	563	417
February	738	537	256	929	688	497
March	642	433	253	1197	663	483
April	849	458	276	942	624	467

* Highest and lowest average value reported in 3-hour periods for each month.

** Mean of the values reported in 3-hour periods for each month.

mean values from month to month, or throughout the day. However, similar to visibility, these results are misleading because the computed standard deviations for cloud ceiling indicate that substantial variability in the data can be expected.

Another interesting question regarding cloud ceilings would be, Is there much difference in ceiling heights recorded during periods of rain and snow mixed as compared to those reported during snow-snow showers? A comparison of the highest and lowest (3-hour average) and mean monthly values obtained for November through April during these weather classes is given in Table 7. For some unexplained reason the results show that the cloud ceilings during mixed rain and snow are consistently lower than those during snow-snow showers. When all values for all months are considered, the percent difference in ceiling heights between mixed rain and snow and snow-snow showers is approximately 25%, which is quite significant.

Pasquill stability index variations. The last weather parameter that was added to the study was the Pasquill stability index. For comparison, the following two questions were thought to be worthwhile: Are there differences in the stability values obtained during fog-ground fog as compared to snow-snow showers? What are the diurnal variations in the stability index during these two weather classes?

A plot of the highest and lowest average Pasquill stability indexes in a season, determined in 3-hour periods for fog-ground fog and snow-snow showers, is shown in Figure 11. Note that only fogs at air temperatures of less than or equal to 0°C were used in this survey. There was a definite diurnal effect as index values were lower for fog-ground fog during the midday hours.

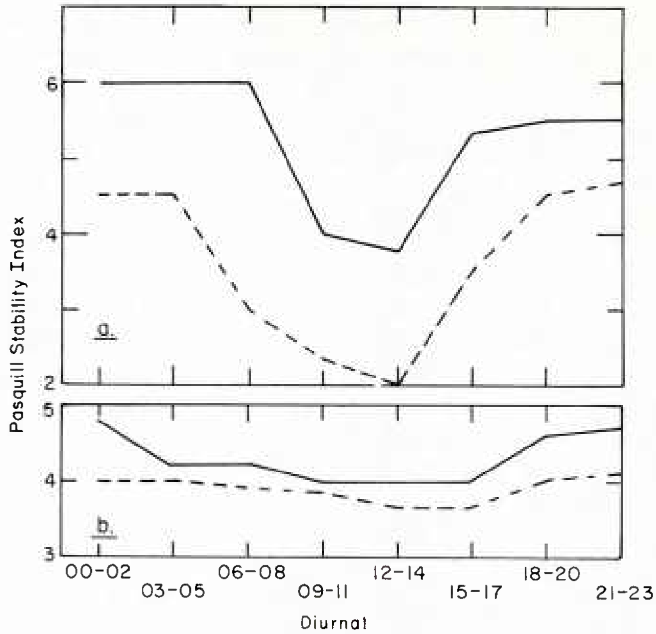


Figure 11. Diurnal average high (solid line and low Pasquill stability index values during (a) fog-ground fog (at air temperatures less than 0°C) and (b) snow-snow showers.

Table 8. Comparison of the Pasquill stability index values.

	Snow-snow showers		Freezing rain-freezing drizzle		Rain and snow mixed	
	High*	Low*	High	Low	High	Low
October	4.80	3.67	--	--	4.14	4.00
November	4.14	3.93	4.33	4.00	4.06	4.00
December	4.17	3.87	4.36	4.00	4.26	4.00
January	4.21	3.85	4.67	4.00	4.11	4.00
February	4.14	3.94	6.00	3.50	4.00	3.75
March	4.15	3.87	--	--	4.22	3.87
April	4.20	3.85	--	--	4.20	3.75

*Highest and lowest average value reported in 3-hour periods for each month, based on the 11-year record.

The average stability indexes for these 3-hour periods for fog-ground fog revealed major variations (ranging from 2.0 to 6.0). The average stability indexes for snow-snow showers, in contrast, vary only slightly through the day (from 3.6 to 4.8).

The average monthly highest and lowest Pasquill stability indexes obtained for three different winter weather classes (snow-snow showers, freezing rain-freezing drizzle, and mixed rain and snow) were also compared (Table 8). There was little variation in the stability indexes between the weather types.

Table 9. List of all reported blowing-drifting snow events between 1 January 1966 and 12 December 1976 with concurrent weather conditions.

Date	Time (local)	Temp (°C)	Humidity (%)	Absolute humidity (g/m^3)	Visibility (km)	Wind speed (m/s)	Ceiling height (m)	Pasquill stability index	Present weather code number
1/11/68	0900	-5	79	2.70	5.0	10.3	600	4	38
1/12/68	1200	-12	72	1.45	15.0	9.2	750	4	36
1/8/70	1500	-4	79	2.91	4.0	10.3	3000	4	36
2/13/70	0500	+3	65	3.84	0.0	18.0	0	4	39
2/13/70	0600	+3	65	3.84	5.0	16.4	0	4	36
2/13/70	0700	+2	69	3.84	0.0	15.4	0	4	39
2/13/70	0900	+2	64	3.58	(>15.0)	16.4	0	4	36
2/18/70	1800	-1	69	3.10	14.0	10.3	360	4	36
3/2/70	0600	-1	74	3.35	8.0	10.8	900	4	38
3/2/70	1800	-1	93	4.20	1.4	9.7	300	4	38
3/2/70	1900	-1	86	3.90	2.5	9.2	360	4	38
3/5/70	1900	-3	93	3.64	1.8	10.8	150	4	38
2/23/73	1000	-0	86	4.18	6.0	7.7	450	4	36
11/27/73	1800	-4	80	2.91	12.0	11.8	1200	4	36
11/27/73	1900	-4	80	2.91	4.0	11.3	900	4	36
11/27/73	2200	-4	86	3.14	1.7	11.3	480	4	36
11/27/73	2300	-4	86	3.14	3.0	9.7	900	4	36
11/28/73	0000	-4	93	3.39	1.8	9.3	750	4	36
11/28/73	0100	-3	86	3.38	9.0	8.2	450	4	36
11/28/73	0200	-3	86	3.38	6.0	9.2	1800	4	36
11/28/73	0300	-4	86	3.14	9.0	7.7	1800	4	36
11/28/73	0600	-4	93	3.39	4.0	10.3	1050	4	36
11/28/73	1300	-3	93	3.64	3.5	9.7	600	4	38
11/29/73	1500	-3	86	3.38	4.0	7.2	240	4	36
11/29/73	1600	-4	86	3.14	8.0	7.7	600	4	36
11/30/73	1500	-4	80	2.91	8.0	6.7	450	4	36

Multiple comparisons of the meteorological parameters

Another suggestion provided by a responder to the questionnaire was to avoid dealing with average values by extracting all cases of the same phenomenon and plotting two or more of the concurrently observed meteorological parameters. This can be done using the basic data (see Table 1). A major drawback, however, would be random gaps in the records. Nevertheless, the suggestion deserves consideration and it was tested using all the hourly observations in which blowing-drifting snow were recorded. Table 9 lists these hourly observations, including time and concurrent meteorological parameters. Of these 26 observed hourly events, 2 were categorized under present weather code 39 (heavy drifting snow, generally high), 6 under code 38 (slight or moderate drifting snow, generally high) and 18 under code 36 (slight or moderate drifting snow, generally low).

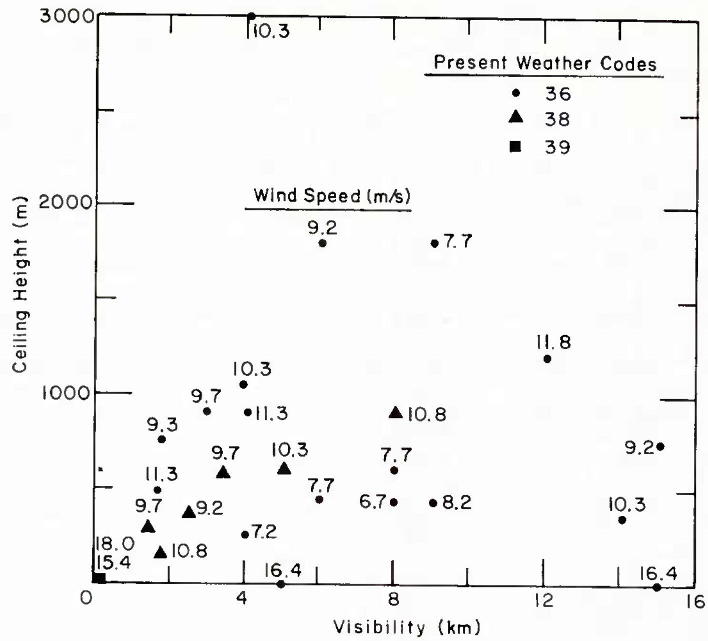


Figure 12. All blowing-drifting snow events observed from January 1966 - December 1976 versus concurrent measurements of visibility, cloud ceilings and wind speed (see text for definition of present weather data).

All of these similar weather events are shown on one graph, Figure 12, together with three concurrent meteorological parameters (visibility, ceiling heights and wind speed). Note that the two code 39 events apparently produced zero ceiling heights and zero visibility. During half of the reported incidents of blowing-drifting snow, the visibility was 5 km or less, and the cloud ceilings less than 1000 m (see Seagraves 1981). Wind speeds in most cases exceeded 9 m/s. A similar diagram that would include temperature, relative humidity and absolute humidity could also be drawn. Since the Pasquill stability index values remained at 4.0 (Table 9) for all 26 events, they were not included in the diagram.

There are other visibility restricting weather conditions that could be considered in such an analysis, for example, "moderate" snowfalls (i.e., weather code 72 and 73 in category C-1 of Table 1).

Limited ceiling and visibility conditions

A number of questionnaire responders were interested in the causes of simultaneous low cloud ceilings and poor visibility. So, the basic data were scanned and all hourly observations were extracted that reported combined weather conditions of visibility less than or equal to 0.5 km and a ceiling height of less than 200 m, and also visibility less than or equal to 1.0 km and a ceiling height of less than 500 m.

A composite of the results for the first of the above two visibility and ceiling limitations (i.e., 0.5 km and 200 m) is given in Table 10. When the number of hours per month are totaled for the 11 years of record, we find that these periods of reduced visibility at Munchen/Riem are most prevalent in October, November and December, and to a lesser degree in January and February. Inspection of the data on a year-to-year basis, however, shows a random distribution. For example, during the winters of 1966-67 and 1974-75 these combined poor visibilities and low ceilings were relatively infrequent; whereas, during the winters of 1972-1973 and 1975-1976, the adverse conditions occurred quite often. The records also show that present weather codes 43, 45, 47 and 49 (i.e., fogs of variable thickness and the sky not discernible) were reported during 79% of the cases. Unreported causes accounted for 12% of the cases, and the rest had a variety of reasons, including other forms of fog and occasionally heavy snowfalls or blowing snow.

A further scan of the original tabulation of the hourly weather records revealed additional observations in which visibilities were less than or equal to 0.5 km or the ceiling heights were less than 200 m. However, since one or the other of the two values were missing they were not included in the preceding survey. Close examination of these particular observations revealed that present weather codes 41, 42, 44 and 46 (i.e., fog in patches or fog of variable thickness with sky discernible) were reported during 32% of these cases. These conditions account for the observations with visibilities of less than 0.5 km but have no information on ceiling heights. Unfortunately, in about 54% of the cases, information on the cause (i.e., weather code) for the poor visibility or low ceiling was also missing. The remaining 14% of the approximately 750 of these hourly incidents were mostly attributed to other forms of fog. The monthly and annual distribution of these particular observations also were found to be very similar to that shown in Table 10.

Two other interesting points should be made regarding combined poor visibility and low ceilings. First, in addition to knowing which months of the year that this is likely, knowing the duration (i.e., number of near-continuous hours) of some of the longer events would be useful. From Table 10 we can assume that there may have been lengthy periods of obscuration in November 1967, October 1969, December 1972 and February 1976. Referring back to the original hourly tabulations for these months, we find that visibilities

Table 10. Number of hours per month during which the observed visibility was less than 0.5 km and at the same time the cloud ceiling height was less than 200 m.

Year	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April
1965-66	-	-	-	-	1	1	0	1
1966-67	5	14	7	1	13	0	0	0
1967-68	5	0	76	27	5	1	1	0
1968-69	0	15	24	16	3	2	4	0
1969-70	2	73	16	22	24	4	1	0
1970-71	1	12	22	17	11	4	3	0
1971-72	2	15	11	6	22	43	14	0
1972-73	7	10	37	66	41	16	3	4
1973-74	0	9	0	9	24	17	2	1
1974-75	5	0	2	0	8	10	2	1
1975-76	11	50	24	22	32	73	0	5
1976-77	10	53	28	55	-	-	-	-
Monthly Totals	48	251	247	241	184	171	30	12

of less than 0.5 km and concurrent ceiling heights of less than 200 m were recorded during 28 hours between 0700 on 22 November and 2300 hours on 23 November 1967, 17 hours between 2100 on 7 October and 0100 9 October 1969, 21 hours between 1800 on 2 December and 2300 3 December 1972, and 36 hours between 1000 on 20 February and 1200 on 23 February 1976.

The other interesting point concerns the general results obtained from the survey in which the higher visibility and ceiling limits (i.e. less than or equal to 1.0 km concurrently with cloud ceiling heights of less than 500 m) were used. These conditions were recorded during 1820 hours of the 11-year record, which is about a 50% increase from the total hours registered for the lower limits. Fog weather codes were predominantly associated with the upper limits. However, about 145 codes for snowfall and a few instances of freezing drizzle indicate that these forms of winter precipitation become more influential at the higher levels.

CONCLUSIONS

In the summary and conclusion section of a report on an atmospheric data workshop for electro-optical, near millimeter wave technology (Hall 1979) it was noted that, "the scientific community needs more environmental detail than is available from climatological data." It was further noted that, "we need to consider different types of instrumentation for routine field use (e.g., the measurement of liquid water content, drop/particle size structures both vertically and horizontally), and perhaps report infrared transmission as we do visibility." The report also states that it is important to work toward a goal of being able to predict the meteorological parameters that will affect future weapon systems and to design them for weather conditions in central Europe.

New and more sophisticated meteorological instruments need to be developed, field tested and used routinely to obtain data directly applicable to E-O sensor problems; this is recognized and being done (e.g., Redfield 1981, Aitken 1982). However, some time is required to establish the accepted meteorological data set that is adequate for the total life cycle of the weapon system (Hall 1979), to test and develop reliable equipment, and to obtain a reasonable record of data from this equipment for locations of interest. Meanwhile, it appeared worthwhile to inspect the meteorological data base currently available for the critical central European region and to determine if further examination and evaluation of the observations would be beneficial.

Although extensive analysis of weather records, including monthly and annual summaries, extreme values, and occasionally information on frequency or probability of occurrence, are given in the literature, details such as diurnal variations, the inspection of different forms of precipitation, and the frequency of two or more concurrently observed meteorological parameters are generally avoided. Such studies, especially those that consider weather data collected during periods of freezing air temperatures (when there are numerous forms of precipitation) would directly address many of the environmental problems defined in the battlefield obscuration program.

This report, therefore, examines the hourly winter weather records for a test station in central Europe and conducts uncommon but potentially useful statistical analyses of the data. Decisions on which meteorological parameters to include in the study were determined from responses to a questionnaire that was sent to several key Department of Defense agencies. The following suggestions were received: 1) investigate six separate categories of winter weather (i.e., snow-snow showers, freezing rain-freezing drizzle, blowing-drifting snow, rain and snow mixed, other freezing hydrometeors combined, and fog-ground fog), 2) separate the incidents of fog into categories defined by 5°C intervals of ambient air temperatures, and 3) include concurrently observed air temperature, relative and absolute humidity, visibility, wind speed, ceiling heights, and the Pasquill stability index.

The basic hourly records for Munchen/Riem were then used to develop several example graphs and tables. These provided essential information related to adverse winter battlefield environmental conditions, such as the knowledge that freezing rain or freezing drizzle is not likely between 1200 and 1700 hours; the variations that can be expected in absolute humidity during fog or ground fog at different temperatures; the frequency and duration of observed periods of poor visibility (less than 0.5 km) combined with low cloud ceilings (less than 200 m); and diurnal and monthly variations in temperature, relative humidity, wind speed and Pasquill stability indexes that one can expect during periods of different forms of freezing precipitation. These and many other similar unique aspects of the weather can be determined from records that are currently available. It is suggested, therefore, that similar investigations be conducted for additional sites in central Europe.

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APPENDIX A: ANNOTATED BIBLIOGRAPHY OF ENVIRONMENTAL STUDIES ASSOCIATED WITH THE BATTLEFIELD OBSCURATION PROGRAM

Avara, E.P. and H.H. Monahan (1981) Climatology module-CLIMAT. In Electro-Optical Systems Atmospheric Effects Library (EOSAEL). Vol. I, Technical Documentation (L.D. Duncan, Ed.). White Sands Missile Range, New Mexico: U.S. Army Atmospheric Sciences Laboratory, ASL-TR-0072.

One of the key inputs to the EOSAEL program is CLIMAT, which contains meteorological data for the approximate period of 1967 to 1980 for 75 stations in central Europe. The data include 11 meteorological surface parameters and 22 weather classes defined by obscuration type.

Biberman, L.M. (1981) Adverse weather and night capability: A call for action. Arlington, Virginia: Institute for Defense Analyses.

This paper discusses acquisition directives about adverse weather effects on electro-magnetic propagation of target signature information as it affects reconnaissance, target acquisition and weapon guidance systems.

Crandall, W.K. (1977) Meteorological analysis for offensive air support. Wright Patterson Air Force Base, Ohio: U.S. Air Force Aeronautical Systems Division, ASD-TR-77-51.

This report provides basic information on the geography, meteorology and other environmental aspects of central Europe, and relates these aspects to the effectiveness of offensive air support. Climatological topics such as persistence of bad weather, and percent frequency of combined occurrences of cloud amount, visibility and precipitation are included.

Cress, T.S. and R.W. Fenn (1978) Climatology of atmospheric aerosols in Europe: Project Opaque. In Optical Properties of the Atmosphere, SPIE, vol. 142, pp. 45-52.

The concentration and size distribution of aerosol particles were measured at six Optical Atmospheric Quantities (OPAQUE) stations in Europe. Standard meteorological measurements of temperature, humidity, precipitation and wind were also made. Vertical profiles made durng October 1976 at Meppen, Germany, show a very pronounced low-level atmospheric haze layer of 1.5- to 2-km thickness.

Essenwanger, O.M. and D.A. Stewart (1978) Fog and haze in Europe and their effects on performance of electro-optical systems. Redstone Arsenal, Alabama: U.S. Army Missile Research and Development Command.

Statistics on frequency of fog occurrence are given using data for several years from 10 stations in central Europe.

Gibson, F.P. (1980) Battlefield obscurants. Vol. 1, Material obscurant categories. Huntsville, Alabama: Lockhead Missile and Space Company, LMSC-HREC-TR-D698315-I.

Specific characteristics of light, medium and heavy graduated levels of rain, fog and snow are developed. The levels are based on a range of extinction values (i.e., wavelength regime) of reasonable operational interest.

Holt, E.H., (Ed.) (1980) Atmospheric data requirements for battlefield obscuration applications. White Sands Missile Range, New Mexico: U.S. Army Atmospheric Sciences Laboratory, ASL-TR-0061.

This report identifies current and future basic atmospheric data that are needed to assess effects on U.S. Army weapon systems that propagate electromagnetic energy through the atmosphere. In addition to the standard meteorological parameters such as temperature, wind, humidity, etc., the report addresses the need for information on adverse weather conditions.

Humphrey, R.G. and W.H. Pepper (1979) Standards for environmental conditions (preliminary). Adelphi, Maryland: U.S. Army Harry Diamond Laboratories.

Snow rate values are given in percent of hourly (or 3 hourly) observations during light, moderate or heavy snowfalls at Wassekuppe, West Germany.

Jackson, G.C. (1979) Icing climatology for northern Europe. Wright Patterson Air Force Base, Ohio: U.S. Air Force Flight Dynamics Laboratory, AFFDL-Technical Memorandum 79-83-WE.

This study develops a series of diagrams that show the percentage probability of encountering icing conditions in the atmosphere. The analysis considers both the vertical and horizontal extents of the atmosphere, and includes data from November-March for the western half of Europe, and from November-April for the eastern half.

Kays, M.D., M.A. Seagraves, H.H. Monahan and R.A. Sutherland (1980) Qualitative description of obscuration factors in central Europe. White Sands Missile Range, New Mexico: U.S. Army Atmospheric Sciences Laboratory, ASL Monograph No. 4.

A qualitative description of obscuration factors in central Europe that could affect E-O systems is given in this monograph. The obscuration factors have four classifications: clear atmosphere, natural obscurants, battlefield obscurants and land-air interface. Adverse winter weather discussions include a brief statement on the occurrence of light to moderate snowfalls over most of the region from November into April, and some statistics on the occurrence of fog in winter.

Keele, E.J. (1979) Methodology investigation on the characteristics of cold-wet weather and related problems. Aberdeen Proving Ground, Maryland: U.S. Army Test and Evaluation Command, TECOM Project 7-CO-RD8-API-003.

A definition of cold-wet weather conditions is established in which near or below freezing temperature in combination with cloudiness, fog, mist, snow, sleet or chilling rain is considered.

Lujetic, V.J. (1979) A report on atmospheric obstructions to visibility. Vol. II, result of literature search. Fort Belvoir, Virginia: U.S. Army Engineer Topographic Laboratories, ETL-0170.

This report collects all currently available information on the effects of atmospheric obstruction on visibility. Volume II includes an extensive literature survey concerning atmospheric effects on visibility, and abstracts of selected publications relating atmospheric obstructions to visibility.

Metzko, J. (1979) Army needs for additional climatic data. Arlington, Virginia: Institute for Defense Analyses, IDA Paper 1444.

This paper addresses needs for climatic data that affect Army field missions and that are not included in the available climatic data base, especially data on aerosols.

Miers, B.T. (1981) Weather scenarios for central Germany. White Sands Missile Range, New Mexico: U.S. Army Atmospheric Sciences Laboratory, ASL-TR-0078.

This report defines a weather scenario as a realistic synthesis of sensible weather over a specified area and time, and develops such scenarios for central Germany. The factors used were: latitude, elevation, terrain features, distribution of land and water, atmospheric pressure center paths, ocean currents, air mass transport and upper level winds. Most of the forms of freezing precipitation that are reported by standard weather station observers were included in the study.

Turner, R.E., P.G. Eitner, C.D. Leonard and D.G.S. Snyder (1980) Battlefield environment obscuration handbook. Science Applications, Inc., SAI Report No. 80-009-AA. Aberdeen Proving Ground, Maryland: U.S. Army Material Development and Readiness Command.

This is a review of available data, models and other information on the performance of visible and infrared sensors and imaging devices under battlefield conditions characterized by various kinds of environmental obscurants. Natural obscurants such as rain, snow, haze and fog are included.

U.S. Army Corps of Engineers (1982) Army environmental sciences. Fort Belvoir, Virginia: U.S. Army Engineer Topographic Laboratories publication, ETL-10.

A new bulletin that provides a medium for exchange of environmental information, including obscuration data.

U.S. Army Electronic Research and Development Command (1978) Atmospheric Sciences Laboratory plan for determining atmospheric effects on electro-optical/millimeter systems operating in a battlefield environment. White Sands Missile Range, New Mexico: U.S. Army Atmospheric Sciences Laboratory, ASL Internal Report.

In addition to the ASL plan, this report discusses the EOSAEL computer module, which will accept meteorological parameters.

Walker, B.F. and R.T. Winn (1980) Climatological statistics on meteorological factors affecting electro-optics in Germany. Eglin Air Force Base, Florida: U.S. Air Force Systems Command, Armament Division, AD-TR-80-61.

This report presents a survey weather scenario for air-to-ground missile deliveries in central Europe. Tables and graphs of cloud cover, ceilings and visibility, humidity, precipitation and refraction are included, as are winter precipitation.

APPENDIX B: REQUEST FOR COMMENTS ON CLIMATOLOGICAL DATA ANALYSIS METHODOLOGY

This Appendix reproduces the letter sent on 23 November 1981.

1. A detailed analysis of freezing precipitation and its relationship with other observed meteorological parameters at Munchen/Reim, West Germany, has been prepared at this Laboratory as part of an on-going program in winter climatology. It is planned to expand the scope of this investigation to consider other locations in central Europe and, in order to assure maximum relevance of this information, we are soliciting comments from a representative group of potential users.

2. Six categories of winter weather:

snow (or snow showers)
cold fogs
freezing rain (or freezing drizzle)
ice needles, granular snow, ice pellets, soft hail
snow and rain mixed
blowing and/or drifting snow

and three concurrently observed meteorological parameters:

air temperature
relative humidity
visibility

were considered in this pilot study.

3. The objectives for analysis of these data were:

a. Provide statistics on the frequency of occurrence of various forms of winter weather that cause a reduction in visibility.

b. Investigate the association between the various freezing weather conditions and concurrently observed meteorological parameters.

c. Select time periods and data intervals appropriate to the limits of the existing data base.

d. Present the results in a diagrammatic form that is readable, useful, and as concise as possible.

4. Examples of the results obtained to date are inclosed. The data were obtained from the USAF ETAC data base though the U.S. Army Atmospheric Sciences Laboratory. They represent the hourly (or 3-hourly) weather observations made at Munchen/Reim, West Germany, for the period 1 January 1966 through 31 December 1976. It is requested that you review the inclosed material and consider the following questions as well as any others pertinent to your requirements:

a. Are the present formats useful and/or adaptable to the needs of the modeling, forecasting and war gaming community?

b. Would absolute humidity values be more useful than relative humidity?

c. What concurrent air temperature limitations and intervals should be used to identify cold fogs?

d. Considering the limitations of the available data base, are there any other critical meteorological parameters or statistical procedures that should be included in the study? For example, would a frequency study of exceptionally poor visibility and its causes by useful? If so, what visibility intervals and limits are best.

e. Should similar analyses for other locations in central Europe be conducted and which stations are of particular interest.

5. Your review of this material o/b 16 October 1981 would be appreciated. The point of contact for this work at USACRREL is Mr. Michael Bilello, AV 684-3282.

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General

Figure 1: Frequency of occurence of visibility-reducing winter weather at Munchen/Riem, West Germany. The monthly frequencies presented in this figure show that snow (or snow showers) and cold fogs are most prevalent, and that freezing rain (or freezing drizzle), and other forms of freezing precipitation (ice needles, granular snow, etc.), are rare (they occur less than 1% of the time) at this location. Blowing (or drifting) snow, occurred too infrequently to be included in this analysis. Since only the predominant weather type is given in the hourly data base, the simultaneous occurrence of freezing precipitation events could not be included in the study.

Snow (or snow showers)

Figure 2: Frequency of occurrence of snow or snow showers on an hourly basis at Munchen/Riem, West Germany. These data illustrate the variation in the occurrence of this type of precipitation that can be expected throughout the day at this location. The frequency of occurrence is given in average number of total hours that the event can be expected per year during each hour of the day. The results show a peak occurrence near 0600 (GMT), and a minimum around 1600 (GMT).

Figure 3: Monthly averages and standard deviations (one sigma) of air temperature, relative humidity and visibility during snow or snow showers, at Munchen/Riem, West Germany. The curves in this figure illustrate the month-to-month variability in temperatures and visibility recorded during snow or snow showers. From October through March the average relative humidity values during snow events are uniform (between 88 and 90%), but could range from 81 to 96%.

Further details of the time distribution of average values of air tempertaure, relative humidity and visibility during snow events are contained in the following three figures:

Figure 4: Average monthly air temperatures recorded during snow or snow showers for 3-hour intervals at Munchen/Riem, West Germany.

Figure 5: Average monthly relative humidity values recorded during snow or snow showers for 3-hour intervals at Munchen/Riem, West Germany.

Figure 6: Average monthly visibility values recorded during snow or snow showers for 3-hour intervals at Munchen/Riem, West Germany.

The isolines in these three figures show the major month-to-month changes, with minor 24 hour variations, displayed by the air temperature and visibility values (Fig. 4 and 6) during snow events. The reverse occurs for relative humidity (Fig. 5), where a day-night influence on this parameter during snowstorms is quite evident.

Cold Fogs

Figure 7: Frequency of occurrence of cold fogs (concurrent air temperatures of less than or equal to +3°C for 3-hour intervals at Munchen/Riem, West Germany. The information in this figure for cold fogs shows that the occurrence of this event reaches a peak in December, and that a slight abatement for all months develops during the daylight hours. It should be noted that the fog statistics in this preliminary study are approximate, because exact upper (warmer) limits of concurrent air temperatures that identify the cold fogs were not specified in our original request for data.

Figure 8: Monthly averages and standard deviations of air temperature, relative humidity and visibility during cold fogs at Munchen/Riem, West Germany. These curves show that month-to-month variability is indicated for all three of these meteorological parameters, with the coldest fogs occurring (as one would expect) in December and January. Estimates of the ambient temperatures (and the probably range) during winter fogs at this location would be speculative without a study such as this.

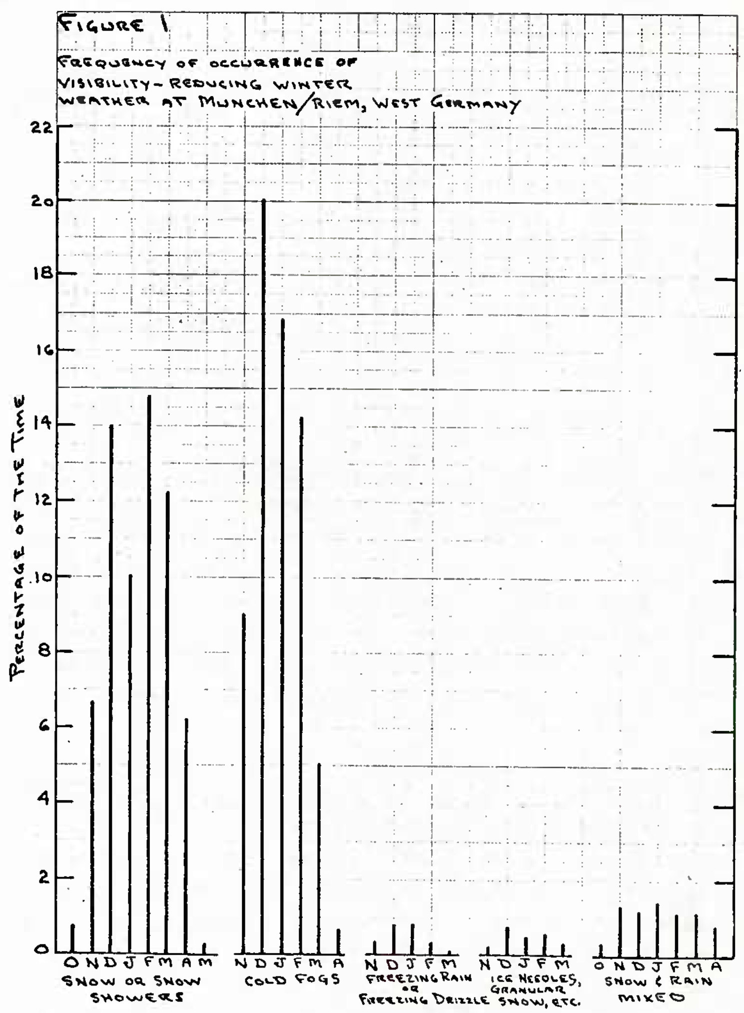
Figure 9: Average monthly visibility values recorded during cold fogs for 3-hour intervals at Munchen/Riem, West Germany. This figure contains additional information on the probable time of reduced visibility during periods of cold fog at Munchen/Riem. The monthly and daily evaluations of these combined meteorological events show that average visibilities of less than 2.5 km can be expected during the midwinter months, and except for a slight reduction in visibility between 0900 and 1400, very little variation occurs throughout the day.

Freezing Rain (or freezing drizzle)

Figure 10: Frequency of occurrence of freezing rain or freezing drizzle on an hourly basis at Munchen/Riem, West Germany. As previously noted, these data show again that freezzing rain (or freezing drizzle) is an uncommon form of winter precipitation at Munchen/Riem. The 24-hour frequency distribution presented in this diagram also shows that the phenomenon does not occur (or becomes negligible) between the hours of 1100 and 1600 (GMT). This mid-day reduction of freezing rain or freezing drizzle has been observed at locations in midwestern United States, and is apparently due to solar heating of the lower atmosphere during those hours.

Figure 11: Frequency of occurrence of freezing rain or freezing drizzle for 3-hour intervals at Munchen/Riem, West Germany. A two-dimensional time distribution (monthly and daily) similar to that shown in Figure 7 was used in this diagram on the frequency of occurrence of freezing rain and freezing drizzle. Total number of minutes (rather than hours) per each three-hour interval per year had to be used here because the event is rarely observed at this location. The isolines in the figure nevertheless reveal that the peak frequency occurs in midwinter and during the nighttime hours.

Figures sent out with questionnaire.



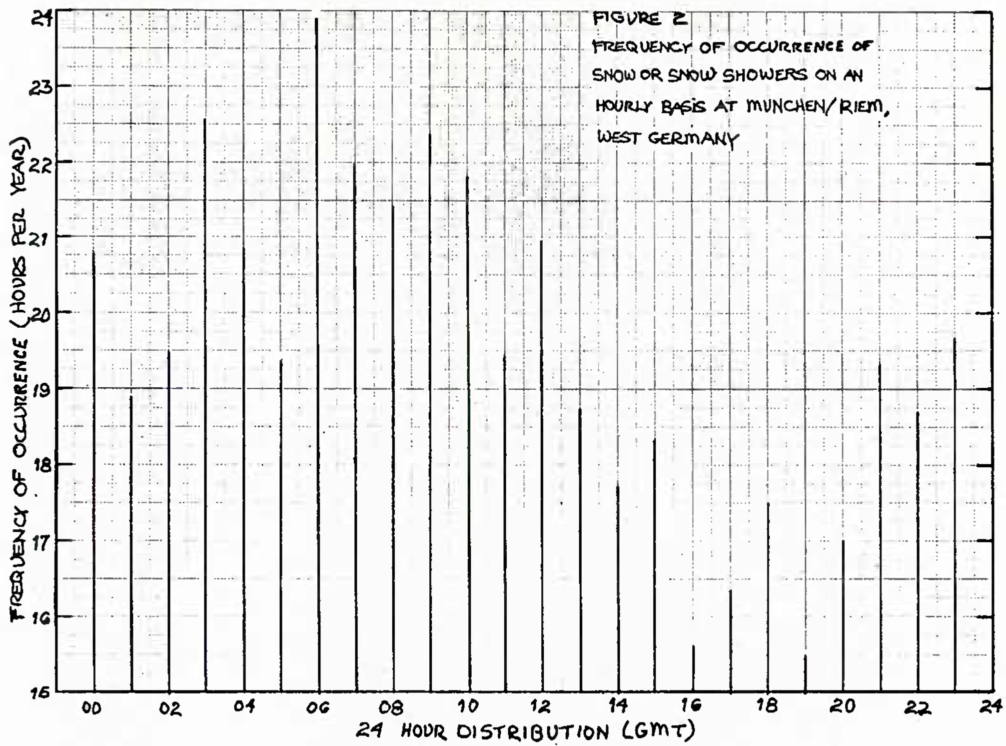


FIGURE 2
FREQUENCY OF OCCURRENCE OF SNOW OR SNOW SHOWERS ON AN HOURLY BASIS AT MUNCHEN/RIEM, WEST GERMANY

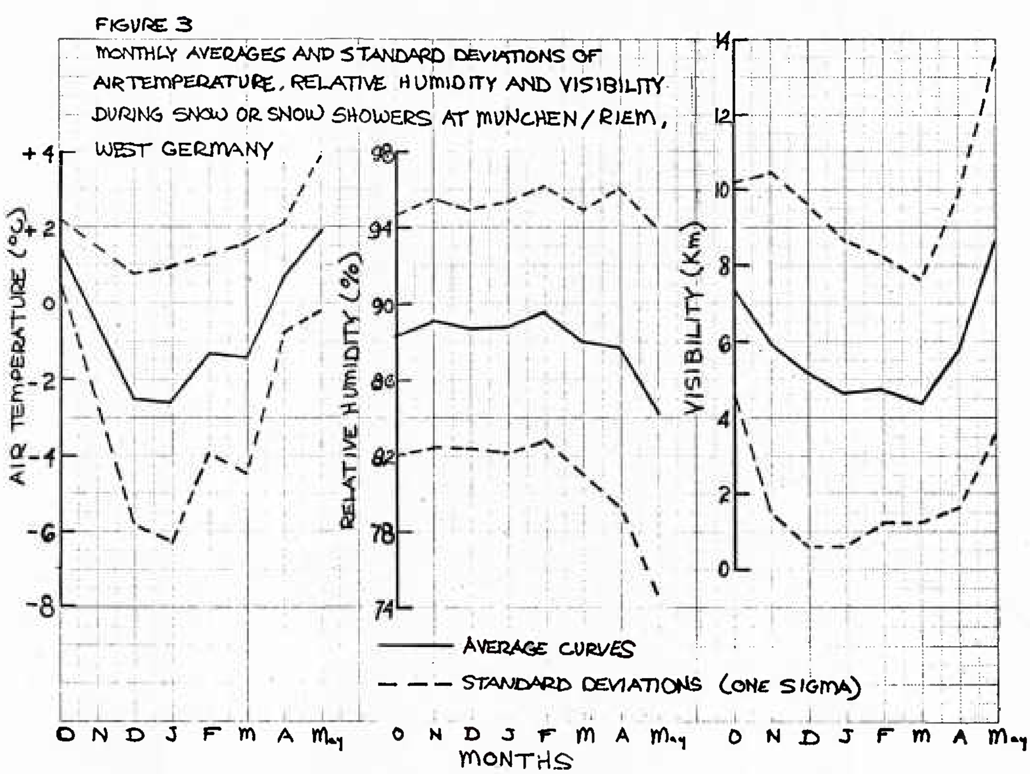


FIGURE 3
MONTHLY AVERAGES AND STANDARD DEVIATIONS OF AIR TEMPERATURE, RELATIVE HUMIDITY AND VISIBILITY DURING SNOW OR SNOW SHOWERS AT MUNCHEN/RIEM, WEST GERMANY

FIGURE 4

AVERAGE MONTHLY AIR TEMPERATURES (°C) RECORDED DURING SNOW OR SNOW SHOWERS FOR 3-HOUR INTERVALS AT MUNCHEN/RIEM

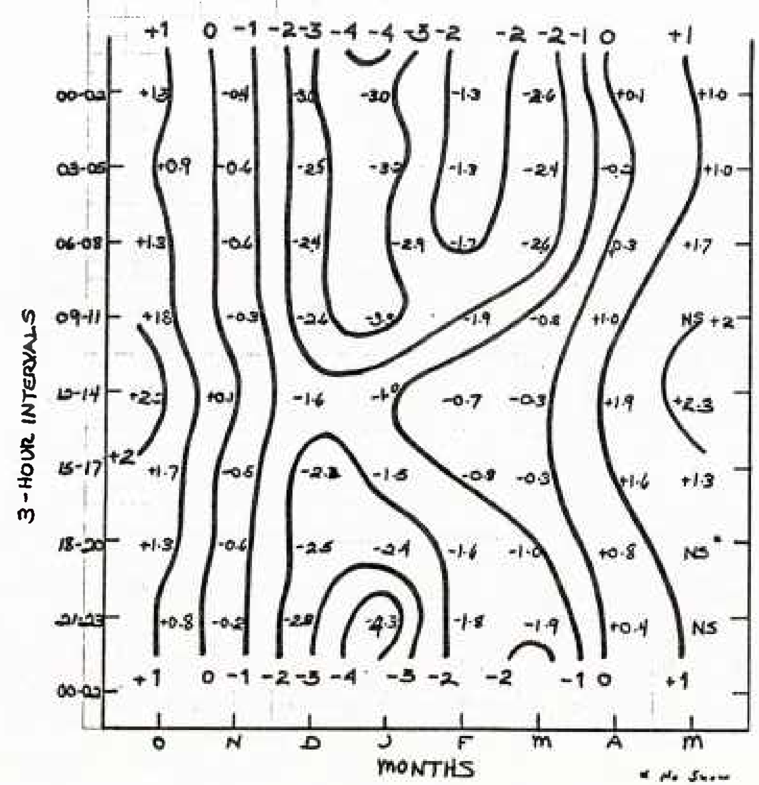


FIGURE 5

AVERAGE MONTHLY RELATIVE HUMIDITY VALUES (%) RECORDED DURING SNOW AND SNOW SHOWERS FOR 3-HOUR INTERVALS AT MUNCHEN/REIM

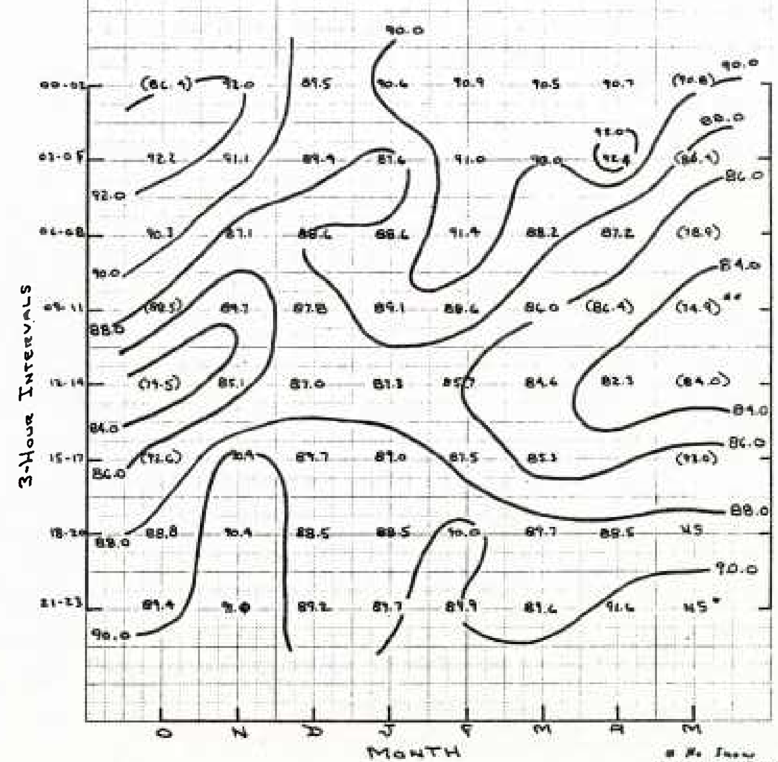


Figure 6
Average Monthly Visibility Values (km)
Recorded During Snow and Snow Showers
For 3-Hour Intervals at Munchen/Reim

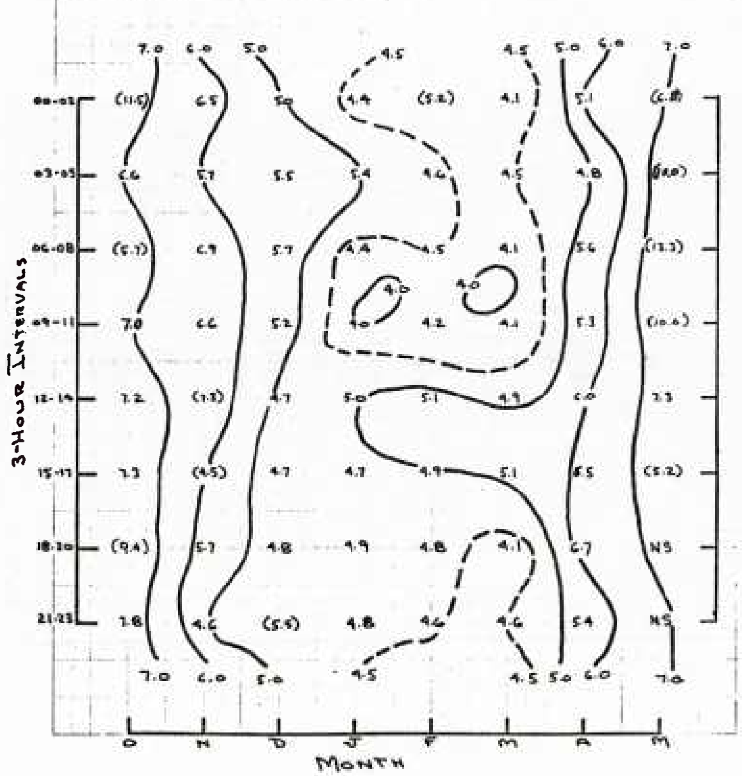
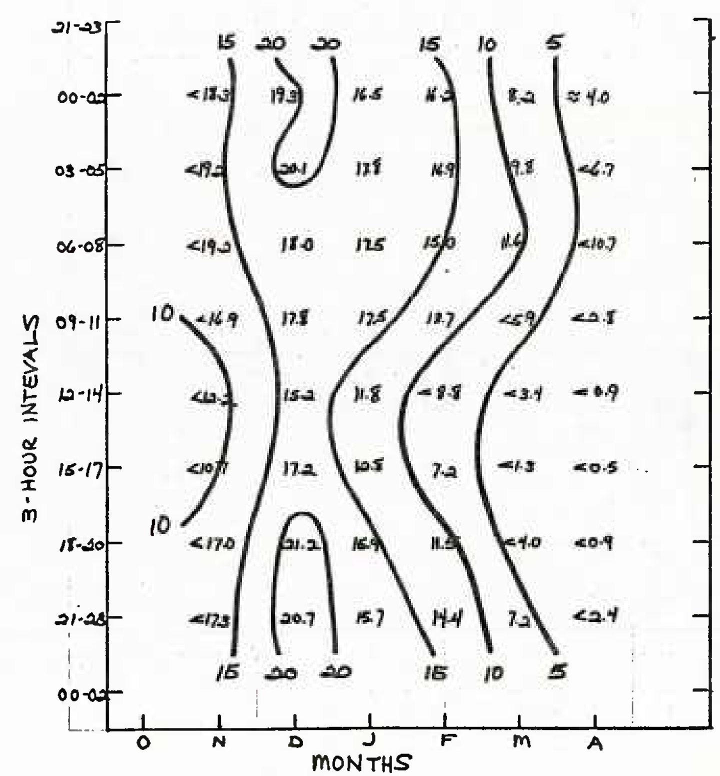


FIGURE 7
FREQUENCY OF COLD FOGS
(CONCURRENT AIR TEMPERATURES OF ≤+3°C)
FOR 3-HOUR INTERVALS (IN TOTAL PROBABLE NUMBER OF HOURS PER YEAR) AT MUNCHEN/RIEM



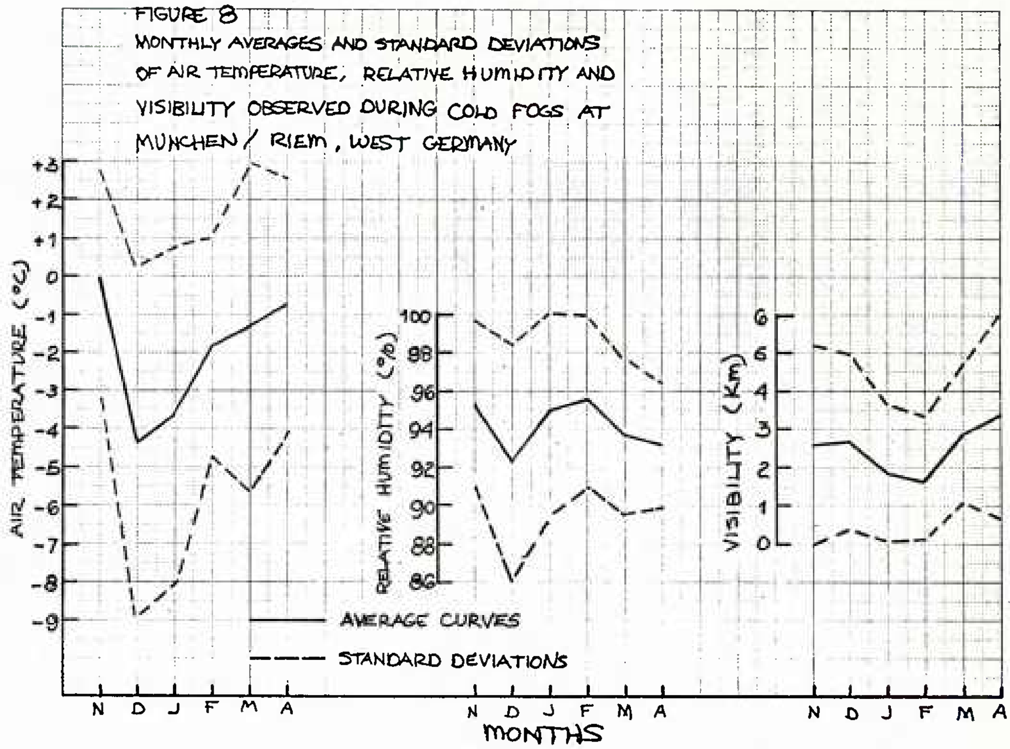


FIGURE 8
MONTHLY AVERAGES AND STANDARD DEVIATIONS OF AIR TEMPERATURE, RELATIVE HUMIDITY AND VISIBILITY OBSERVED DURING COLD FOGS AT MUNCHEN / RIEM, WEST GERMANY

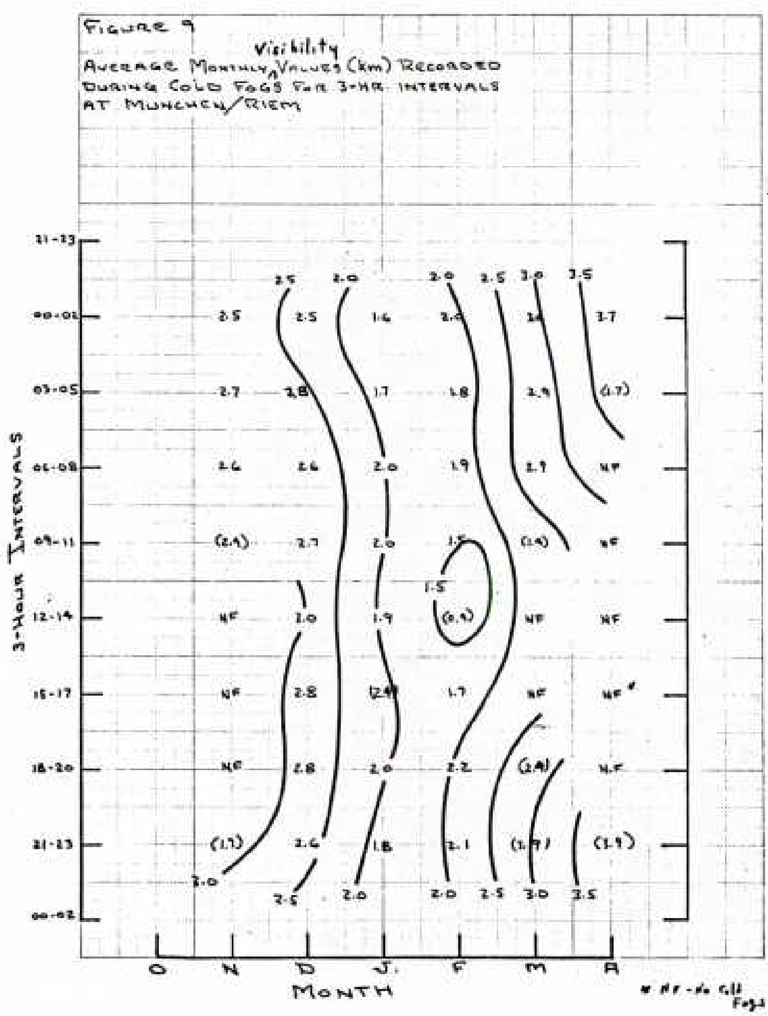


Figure 9
Average Monthly Visibility Values (km) Recorded During Cold Fogs For 3-HR. Intervals At Munchen/Riem

FIGURE 10

FREQUENCY OF OCCURRENCE OF FREEZING RAIN OR FREEZING DRIZZLE ON AN HOURLY BASIS AT MUNCHEN/RIEM

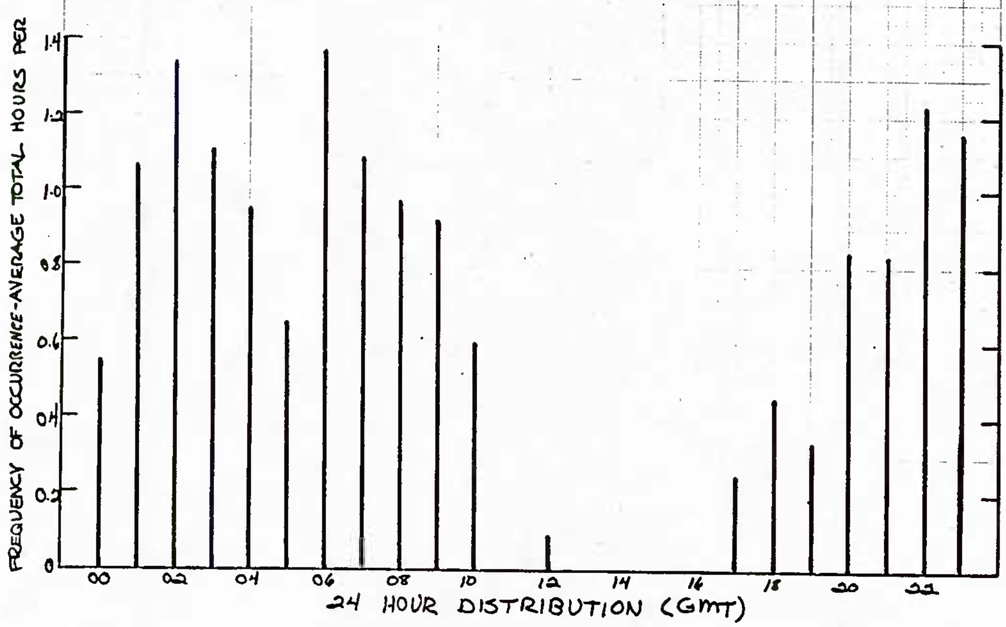
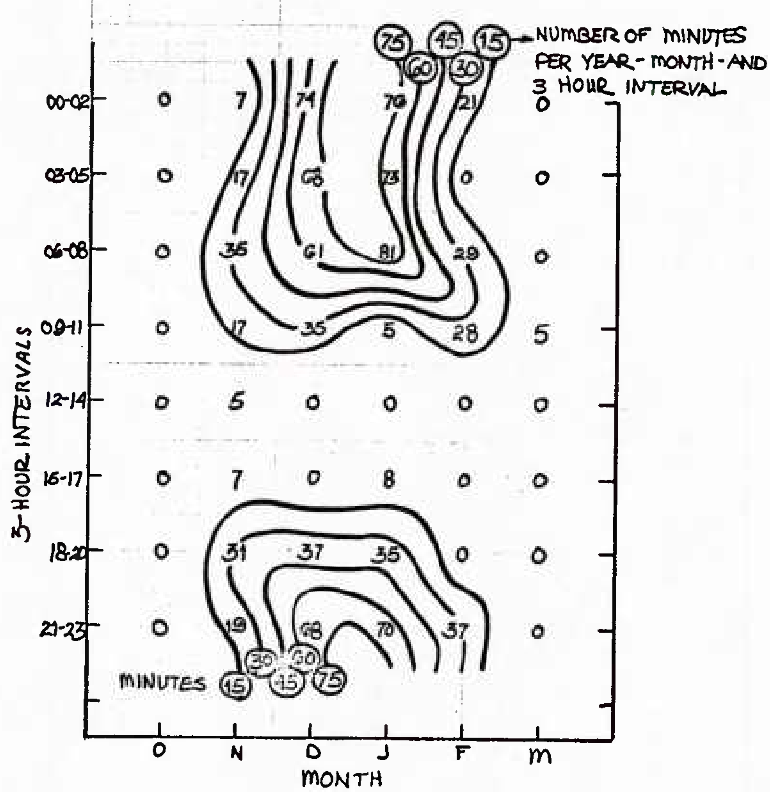


FIGURE 11

FREQUENCY OF OCCURRENCE OF FREEZING RAIN OR FREEZING DRIZZLE FOR 3-HOUR INTERVALS AT MUNCHEN/RIEM, WEST GERMANY



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