FROZEN PRECIPITATION AND CONCURRENTLY OBSERVED METEOROLOGICAL CONDITIONS

by

Michael A. Bilello
U.S. Army Cold Regions Research and Engineering Laboratory
Hanover, New Hampshire

ABSTRACT

This study evaluates statistical data for two or more meteorological parameters, recorded concurrently during the winter. The analysis considers only freezing forms of precipitation, placed into seven categories, and correlated with simultaneously observed atmospheric conditions, such as temperature, humidity and wind speed. Computer tabulated data from 11 years of winter weather for Munchen/Riem, West Germany, were obtained for the investigation. Typical results are: 1) the variations in absolute humidity values that can be expected during periods of fog or ground fog at different air temperatures, 2) the likelihood that freezing rain or freezing drizzle will occur least frequently between 1200 and 1700 hours, and 3) the diurnal and monthly air temperatures, relative humidity and visibility values that can be expected during periods of snow and snow showers. These are examples of the unusual and interesting environmental knowledge that can be gained from available climatic records; similar investigations can be conducted for other sites that have long-term weather records in computer-based files.

INTRODUCTION

An important climatological relationship seldom studied is the coincidence of two or more atmospheric parameters. Usually each weather element is evaluated separately, and monthly or annual averages and occasionally maximum and minimum or extreme values are provided. 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, or what would the probable range in air temperature be during selected periods of freezing precipitation? A correlation of different types of winter precipitation with other concurrently observed meteorological parameters would be very useful, for example, in the design and construction of roads, runways and buildings or solving the problems associated with the atmospheric effects on electro-optical weapons systems.

A few investigators have conducted statistical studies of the simultaneous occurrence of two or more meteorological parameters (Bilello 1971, Crandall 1977, Keele 1979, Walker and Winn 1980, Miers 1981, Avara and Monahan 1981). 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. The frozen precipitation is separated into specific categories and then correlated with key simultaneous weather conditions such as temperature, humidity and visibility. This study is presented as an example of what could be done with available records, and is designed to be applicable to other weather stations with long-term meteorological records on computer files.

ATMOSPHERIC PARAMETERS, DATA SOURCE AND DATA REDUCTION

The hourly weather observations used in this study were recorded at Munchen/Riem Weather Central, Federal Republic of Germany, located at latitude 40°09' N and longitude 11°43' E. The period of record used here, 1 January 1966 through 31 December 1976, was selected because it had become established as the standard climatic record to be used for any studies associated with an on-going atmospheric obscuration program.

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. The 39 freezing weather codes were divided into five general groups: 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. Huschke (1980) presents brief descriptions of some of the above types of weather.

Fog was the sixth weather type, and were separated into five consecutive 5°C intervals by concurrent air temperature (5°C > T > 0°C; 0°C > T > -5°C; -5°C > T > -10°C; -10°C > T > -15°C; -15°C > T).

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.

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LISTING OF HOUPLY OBSEPVATIONS CONTAINING PERTINENT FRESENT 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 CODFS 27,76-79,87-90,96,99.
        C-4 (FOG AND GROUND FOG) - WW CODES 10-12,28,40-49.
        C-5 (BLOWING SNCW) - 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 LF -15 C)
        C-8 (FOG AND GROUND FOG WITH -15 LT TFMP LE -10 C)
        C-9 (FOG AND GROUND FOG WITH -10 LT TFMP LE -5 C)
        C-10 (FOG AND GROUND FCG WITH -5 LT TEMF LE 0 C)
        C-11 (FCG AND GPOUND FOG WITH 0 LT TEMP LE 5 C)

TEMPERATURES ARE IN DEGRFES CELSIUS, RELATIVE HUMIDITIFS ARE IN PEPCENT, APSOLUTE HUMIDITIES
   VISIBILITIES APE IN KMS, WIND SPFEDS ARE IN MPS, AND CFILING HEIGHTS ARE IN METEPS.


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    92.09      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    95.67      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
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Data reduction and computation format

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. 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. Consequently, all events reported during sequential 3-hour intervals were used instead.

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.

For example, the value 9.87 for 0000 to 0259 hours in Table 2 means that, 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.

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), and cloud ceiling heights (m). By use of the data base given in the hourly observation tabulations (e.g., Table 1), the arithmetic means and 1-sigma standard deviations of these concurrently observed atmospheric parameters were calculated.

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

	TIME OF DAY (LST)							
MONTH	00-02	03-05	06-08	09-11	12-14	15-17	18-20	21-23
JAN	9.87	9.39	10.06	10.29	10.27	8.33	8.71	9.30
FEB	12.19	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

GRAPHING THE DATA

Based on previous surveys of frozen precipitation (Bilello 1971, 1974) and suggestions received from reviews by colleagues, the data for Munchen/Reim were interpreted and presented in graphs or tables, as follows.

Monthly frequency

Monthly frequency values for each of the general weather groups were shown as bar graphs because they compactly displayed the frequencies and permited comparisons between the weather groups (Fig. 1). Note that only the fogs with concurrent air temperatures equal to or less than 0°C 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 at Munchen/Riem. They peak during December, and 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.) are relatively infrequent. Blowing-drifting snow also occurred too few times during the 11-year record to be included in Figure 1.

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., Table 2) of the frequency values for

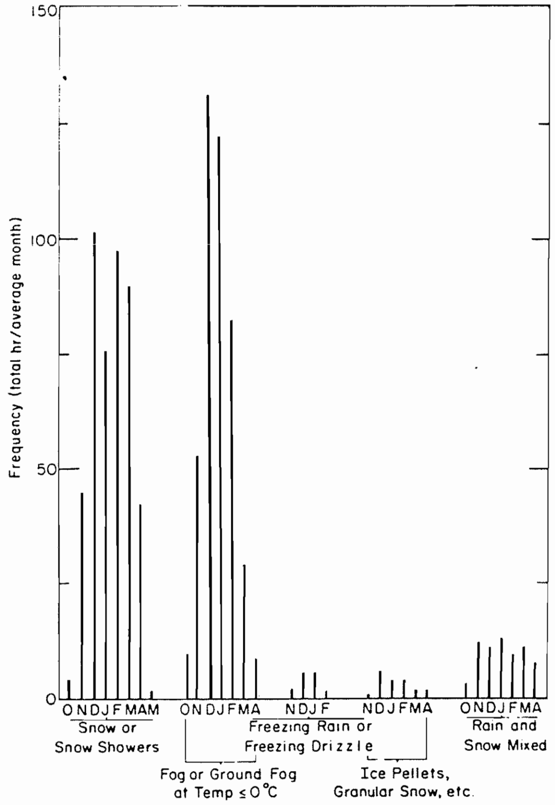


Figure 1. Monthly frequency distribution of various forms of freezing weather. Values are averages based on the 11-year record.

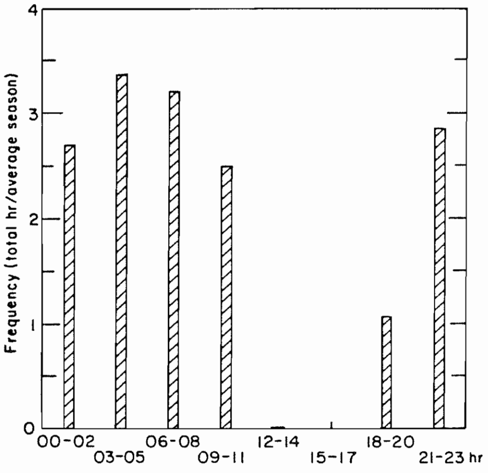


Figure 2. Diurnal frequency distribution of freezing rain-freezing drizzle. Values are averages based on the 11-year record.

3-hour intervals can provide this information. 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 throughout a winter day. The graph clearly shows that freezing rain or freezing drizzle hardly ever occurs between 1200 and 1700 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 during certain aviation operations, such as aerial photographic missions.

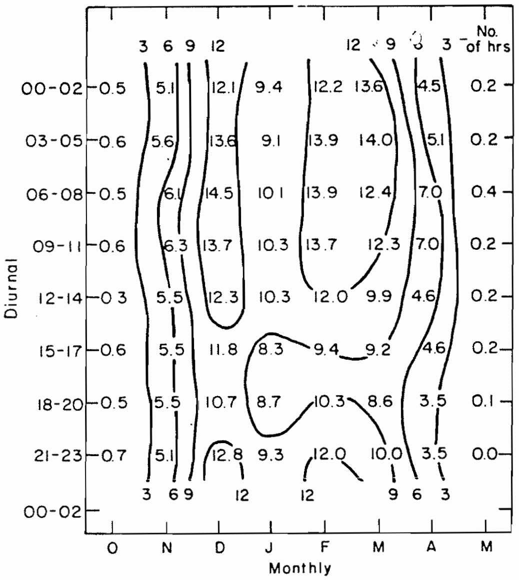


Figure 3. Diurnal frequency distribution of monthly totals for snow-snow showers (total hours/average season). Values are averages based on the 11-year record.

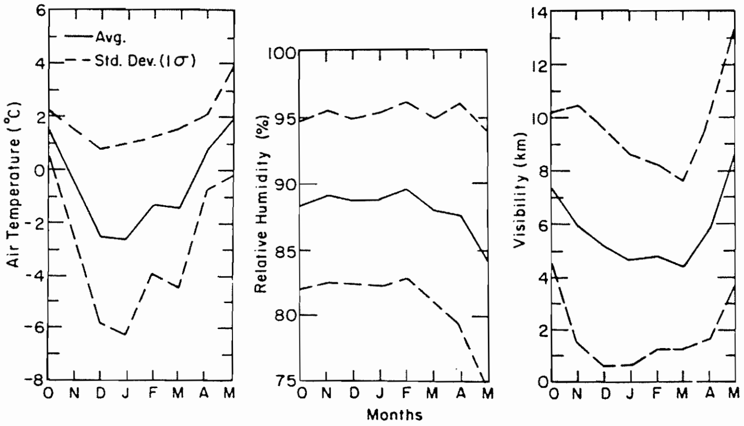
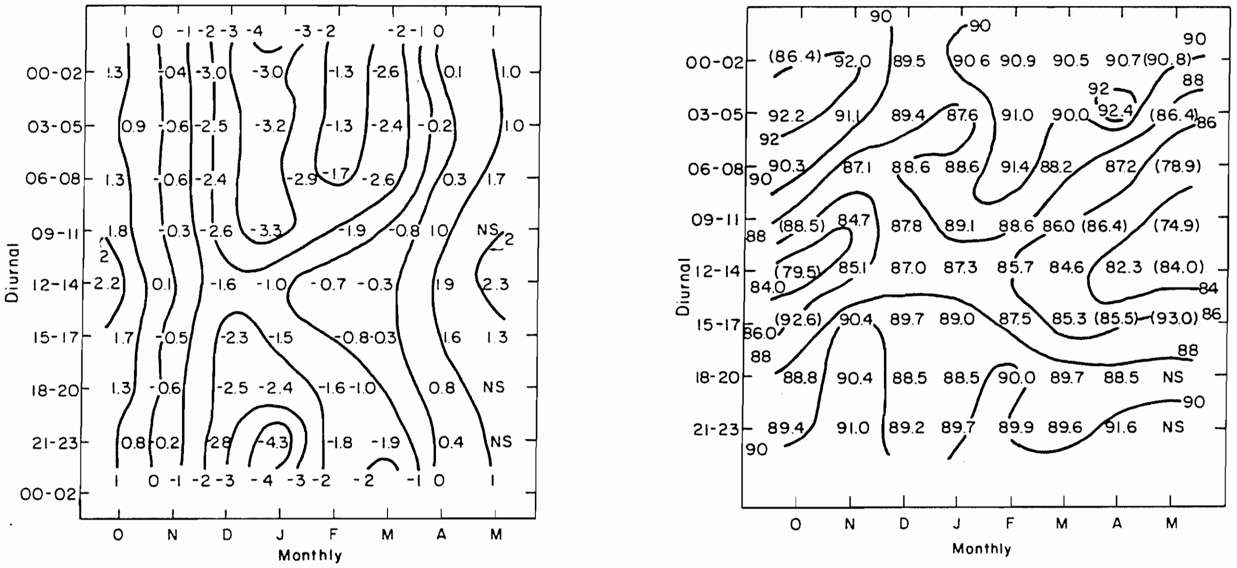


Figure 4. Monthly means and standard deviations of air temperature, relative humidity and visibility recorded during snow-snow showers (based on 11-year record).

Graphs of concurrent meteorological parameters

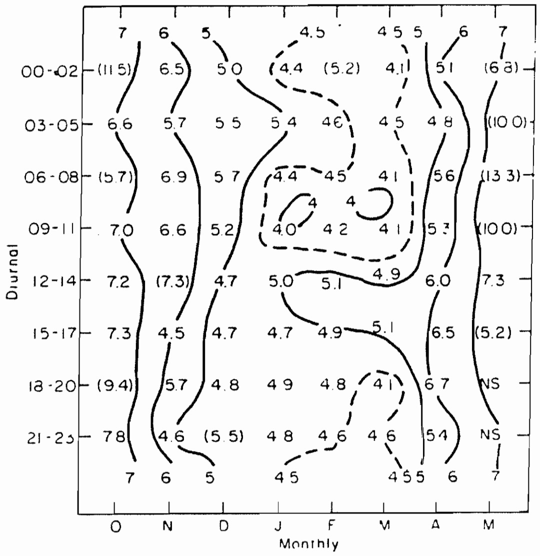
Because six basic winter weather groups and seven different concurrent meteorological parameters were identified for this study, it would be impractical to graph all possible combinations of these variables. A few graphs of some interesting combinations will instead be given as examples (Fig. 4, 5a, 5b and 5c).

The curves in Figure 4 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%. The isolines in Figures 5a, 5b and 5c show the major month-to-month changes, with only minor daily variations, displayed by the air temperature and visibility values (Fig. 5a and 5c) during snow events. The daily variations for relative humidity (Fig. 5b) are much greater.



5a. Air temperature (°C).

5b. Relative humidity (%).



5c. Visibility (km).

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.

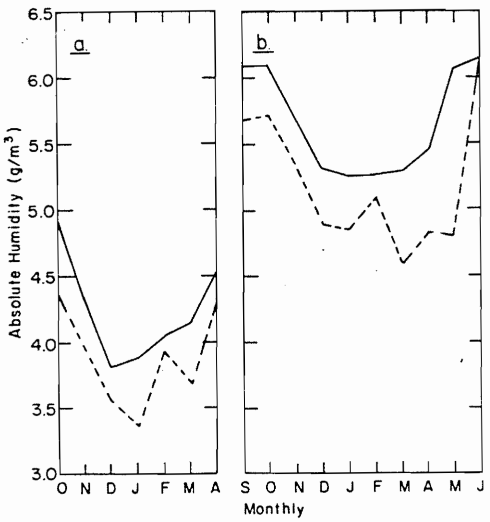


Figure 6. Monthly distribution of the highest (solid line) and lowest absolute humidity values (averages for 3-hour intervals, based on 11-year record) observed during (a) snow-snow showers and (b) fog-ground fog at temperatures of 0° to 5°C.

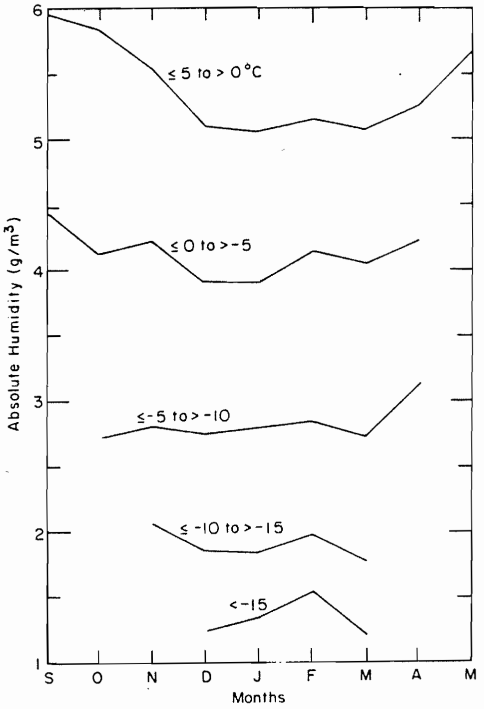


Figure 7. Mean monthly absolute humidity values observed during fog-ground fog at various air temperatures (based on 11-year record).

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 specific locations.

Absolute humidity variations. Both relative humidity and absolute humidity values are generally required. For example, relative humidity is used in deriving fog particle size distributions 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?

The results shown in Figure 6 provide the answers. The 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 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. 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.

Wind speed variations. A typical question on wind speed variations during periods of inclement weather would be, Do wind speeds differ markedly during various forms of winter weather? If so, what are the observed differences? 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 large differences between wind speed recorded during the snow and those during freezing rain were unexpected.

Ceiling height variations. Another extremely variable meteorological condition is 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. A type question that may arise 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 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 3. For some unexplained reason the results show that the cloud ceilings during mixed rain and snow are consistently lower than those during snow-snow

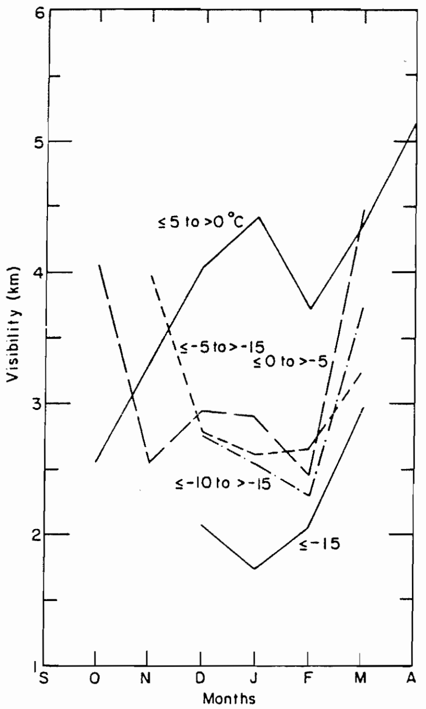


Figure 8. Mean monthly visibility values observed during fog-ground fog at various air temperatures (based on 11-year record).

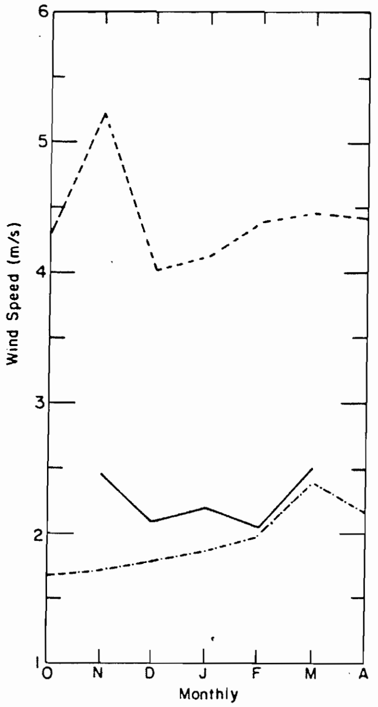


Figure 9. Mean monthly wind speed values observed during snow-snow showers (dashed line), freezing rain-freezing drizzle (solid line), and fog-ground fog (dot-dash line).

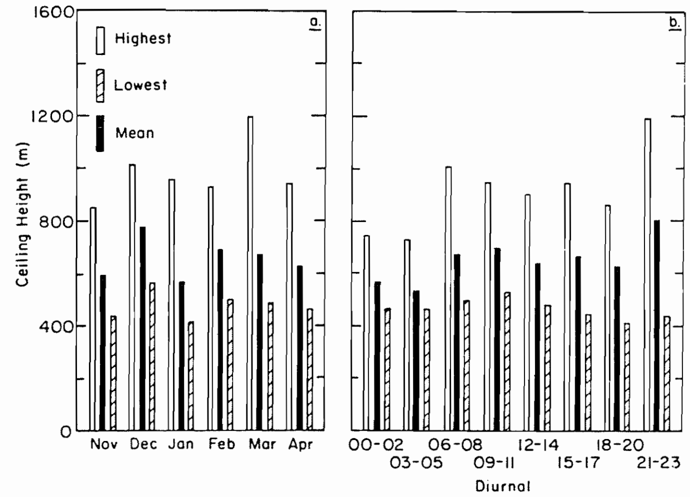


Figure 10. Monthly (a) and diurnal (b) distribution of cloud ceiling heights recorded during snow-snow showers.

Table 3. 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.

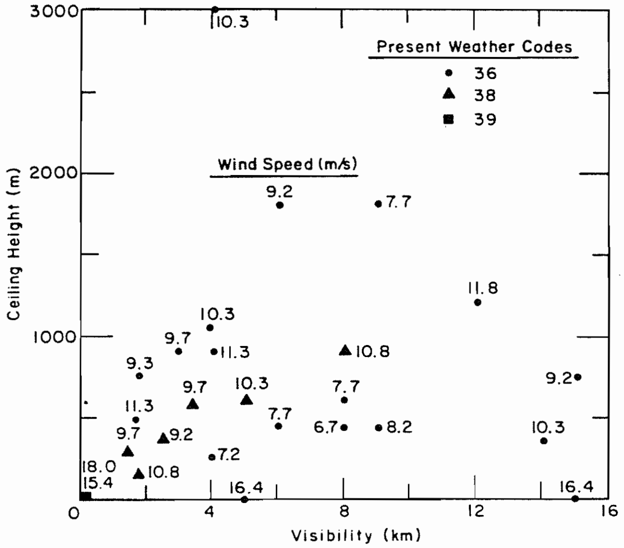


Figure 11. All blowing-drifting snow events observed from January 1966 - December 1976 versus concurrent measurements of visibility, cloud ceilings and wind speed (see text for definition of present weather data).

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.

Multiple comparisons of the meteorological parameters

To avoid dealing with average values, all cases of the same phenomenon can be extracted and two or more of the concurrently observed meteorological parameters can be plotted. This can be done using the basic data (see Table 1). A major drawback, however, would be random gaps in the records. Nevertheless, this idea was tested using all the hourly observations in which blowing-drifting snow were recorded. Of the 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).

All of these similar weather events are shown on one graph, Figure 11, 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. 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.

CONCLUSIONS

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 more recent and demanding environmental problems.

This paper, 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. These analyses were based on decisions to: 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, and ceiling heights.

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 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, and wind speed 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.

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