

**A RAND NOTE**

**"Typical Weather" Months in the Past  
(1973-1983) in Central Europe**

**Ralph E. Huschke**

**March 1988**

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**Prepared for  
The United States Air Force**

*40 Years*  
1948-1988  
**RAND**



## PREFACE

As a pioneer in accounting for weather factors in air-land warfare studies, RAND is currently upgrading its capability to handle the effects of weather and weather information in air and land combat simulations. The objective is to allow "real weather" to influence operations and realistically uncertain forecasts of the "real weather" to influence decisions.

This requires designing a weather module that incorporates weather data, effects, and forecasts, and is compatible with the family of C<sup>3</sup> and warfare models that will exist in RAND's new Military Operational Simulation Facility (MOSF). This activity has four phases:

1. Structuring historical data on a space-time grid;
2. Determining periods of "typical" weather;
3. Developing weather forecast algorithms;
4. Developing weather-effects algorithms for both air and land operations.

Phase 1 for central European weather was completed in January 1987. It utilizes the USAF Environmental Technical Application Center's (ETAC) DATSAV-Surface database, a computerized archive of global weather data. RAND's most complete subset of those data covers the 11-year period from January 1973 through December 1983. Data are available every three hours in 217 zones that cover the United Kingdom, Netherlands, Belgium, Luxembourg, Denmark, Federal Republic of Germany, northern France, East Germany, Czechoslovakia, and Poland.

Phase 2 is documented in this Note. It determines historical periods of central European weather that reliably typify average weather conditions for any chosen season. Thus, the inadvertent use of periods of unusually good or bad weather can be avoided. Conversely, this Note also identifies "worst case" and "best case" weather periods that can be used to establish "weather bounds" on study results.

The results of this Note are currently being used in a RAND Project AIR FORCE study entitled "Air Support of the Land Battle: Interdiction Concepts," wherein data for June 1974 and January 1981 are used to represent typical summer and winter conditions, respectively.

This Note is being published for distribution outside of RAND to provide others with a guide for the selection of weather data for use in air-land war games and warfare simulations in central Europe in which weather conditions are represented by historical data.

## SUMMARY

**Monthly periods of central European weather are ranked according to their "typicality"** in terms of both ceiling and visibility (aviation weather) and precipitation. The rankings cover all months in the years 1973 through 1983. The area representing central Europe is a broad band centered on the eastern border of West Germany, from Denmark to Austria, extending some 100 to 200 km into both NATO and Warsaw Pact territories.

Long-term (11-year) monthly average frequencies of good, bad, and marginal aviation weather are calculated and compared with individual monthly frequencies to generate indexes of typicality. The indexes combine a measure of good-day/bad-day departures from average frequencies and a measure of spatial variability. For the precipitation analysis, long-term and individual monthly precipitation and snowfall frequencies are similarly compared.

The months that represent the most typical, best, and worst of aviation weather for the four seasons are shown in Table S.1. In addition to the individual monthly rankings, **near-typical multimonth (seasonal) periods are identified for air operations.**

With regard to frequency of precipitation (rain and snow), the months that best typify the four seasons are January 1980, May 1981, June 1978 (or July 1973), and September 1974. Snowfall frequency is best typified by January 1982.

**Typical aviation-weather and precipitation months rarely coincide, but complete comparative data are given** to assist judgments where both types of weather factors may be important.

Table S.1

SUMMARY OF TYPICAL AND ATYPICAL AVIATION-WEATHER MONTHS  
BY SEASON IN CENTRAL EUROPE

| Season | Most Typical Month | Best Months                   | Worst Months             |
|--------|--------------------|-------------------------------|--------------------------|
| Winter | January 1981       | January 1983                  | January 1973             |
| Spring | March 1977         | April 1974<br>April 1982      | April 1978               |
| Summer | June 1974          | July 1977<br>June 1979        | August 1977<br>July 1980 |
| Fall   | September 1978     | November 1977<br>October 1980 | October 1977             |



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## I. WHAT IS "TYPICAL" WEATHER?

Typical weather must relate to some form of long-term average occurrence frequencies of some relevant weather conditions. For tactical combat in central Europe, the most relevant weather conditions are cloud ceiling, surface visibility, and precipitation. These considerably affect both air and land operations.

The period of time over which the "long-term" frequencies are calculated is somewhat limited by the duration of the highest quality surface weather database,<sup>1</sup> the USAF Environmental Technical Application Center's (ETAC's) DATSAV-Surface database, a computerized archive of global weather data that has undergone good quality control only since 1973. RAND's most complete subset of those data for Europe covers the 11-year period from January 1973 through December 1983. This period is the "long term" in our statistical calculation.

Weather must also be defined as being typical of a particular time of year. In central Europe, the annual cycles of ceiling and visibility frequencies have large amplitude, as illustrated for Berlin in Figs. 1 through 3.<sup>2</sup> Clearly, typical weather based on year-round frequencies would have little practical meaning; such weather might be typical of March or October, but certainly not of the other 10 months. Fairly homogeneous winter (November through February) and summer (May through August) seasons might be defined, but subsequent analysis of the 11 years of data revealed that, even within these seasons, there are many month-to-month differences that complicate reasoning as to the typicality of the seasons. We therefore decided to use the month as the unit of time for which "typical" is determined.

Typical weather must represent a locality or region. Spatial variability of weather within the region should be accounted for. A

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<sup>1</sup>Highest quality in terms of time and space density, as well as accuracy.

<sup>2</sup>Figures 1, 2, and 3 taken from R. E. Huschke, R. R. Rapp, and C. Schutz, *Military Weather Calculations for the NATO Theater: Weather and Warplanes VIII*, The RAND Corporation, R-2401-AF, April 1980.

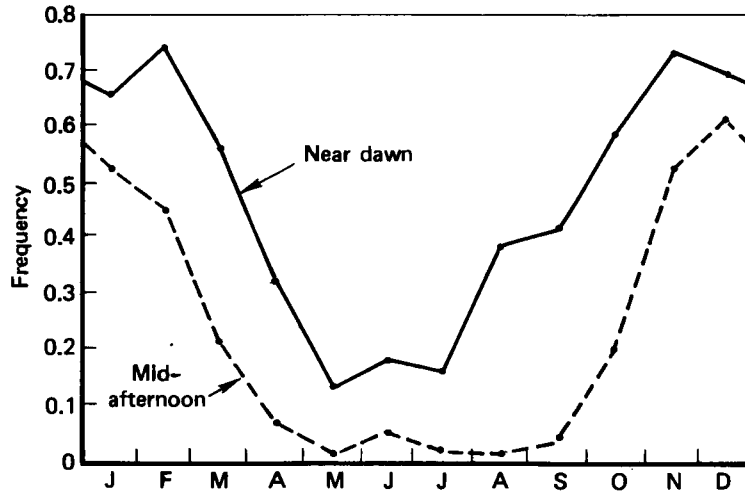


Fig. 1 -- Monthly frequencies of low visibility (< 5 mi) at two times of day at Berlin

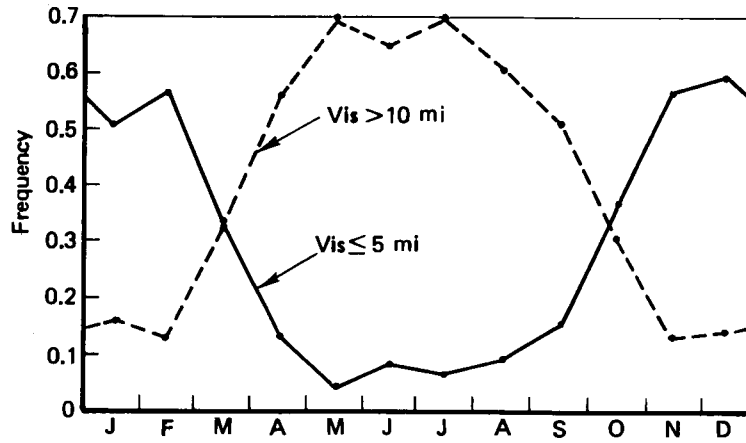


Fig. 2 -- Monthly frequencies of high and low visibilities at Berlin



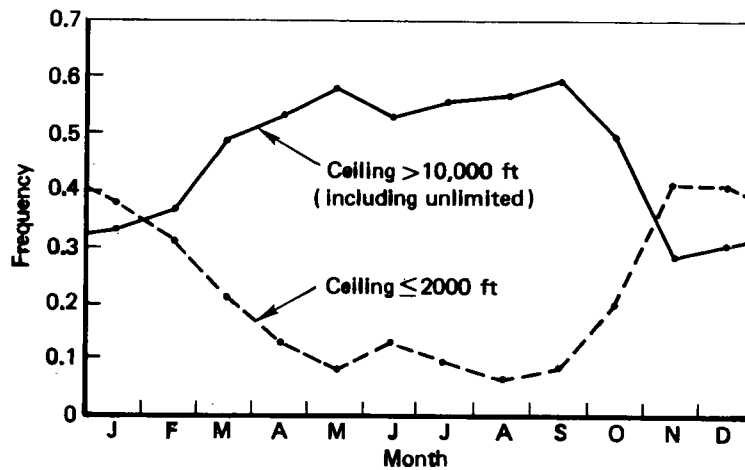


Fig. 3 -- Monthly frequencies of high and low ceilings at Berlin

typical month throughout a region should be one whose weather frequencies most nearly match the long-term frequencies in all parts of the region, not one that appears "typical" overall because one half of the region is abnormally good and the other half abnormally bad.

The selection of a region in central Europe for the typicality analysis must strike a compromise between a small enough area so that spatial variability is tractable and a large enough area to represent the main theater of combat. The solution found in this study was to define a broad band centered on the inter-German and West German-Czechoslovak borders, extending 100 to 200 km into both NATO and Warsaw Pact territories. That band was then divided into four east-west corridors, each containing from 9 to 18 locations for which the 11-year weather database contains data. These corridors are labeled A to D from north to south in Fig. 4.

A month having "typical weather," therefore, is a month in which the relevant weather condition occurrence frequencies have minimal departures from their long-term average frequencies for the same month, and there is minimal variation among the departures in the four corridors.

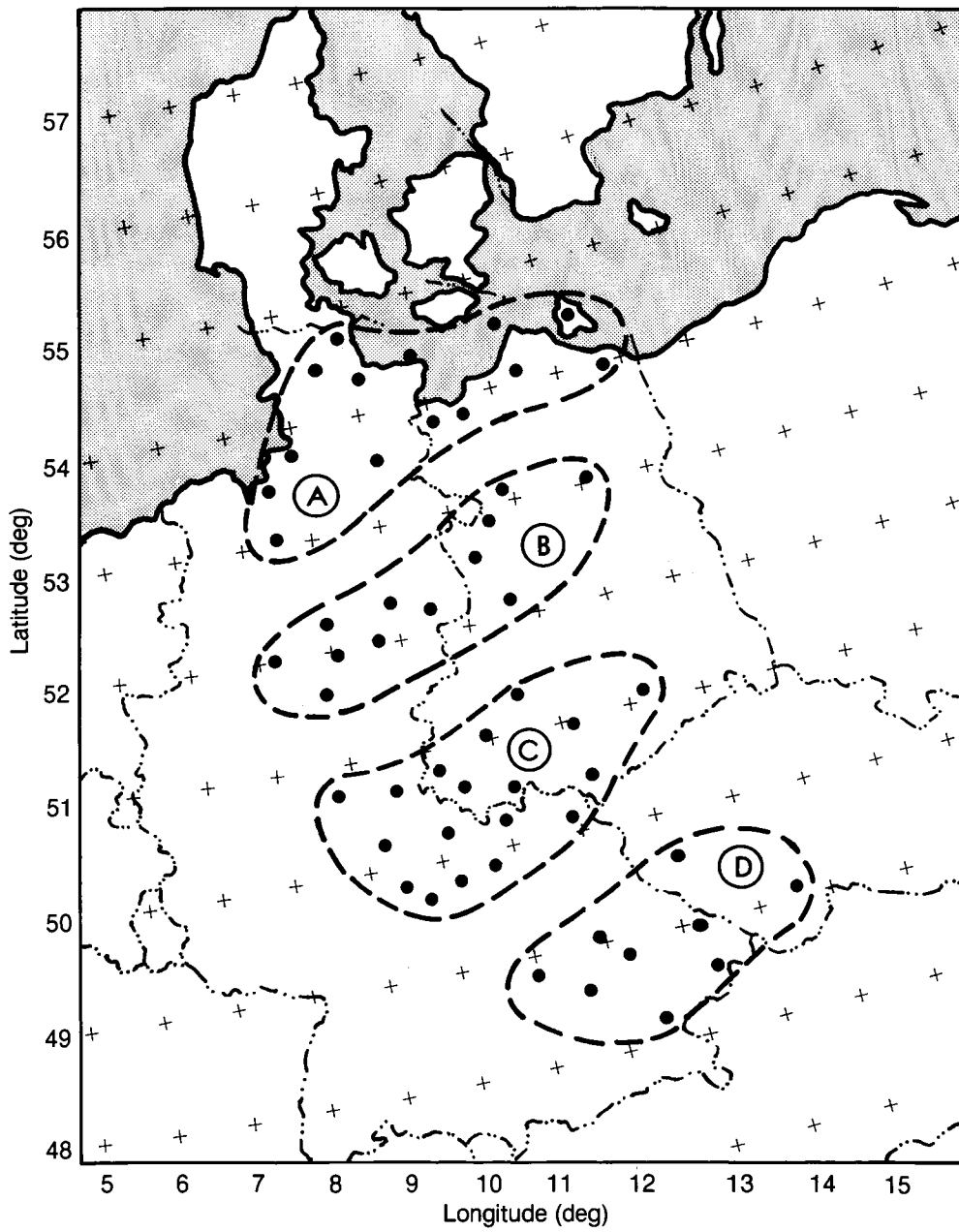


Fig. 4 -- Approximate locations of weather stations whose data were used in this study

## II. MONTHS HAVING TYPICAL AVIATION WEATHER (CEILING AND VISIBILITY)

The most relevant weather conditions for aviation in the four corridors would be ceilings and visibilities affecting the low-altitude ingress and egress of ground attack aircraft. "Good, marginal, and bad" weather conditions for low-altitude terrain avoidance are defined by ceiling/visibility thresholds for each corridor, as shown in Table 1, with due consideration for greater terrain ruggedness in the south than in the north.

Every weather observation, each daylight hour in each day in each corridor, is categorized as good, marginal, or bad. A simple numerical scheme and aggregation of all weather observation categories in each corridor in one day permits designating each corridor-day as being good, marginal, or bad.

Table 1

### WEATHER THRESHOLDS

| Corridor | Condition | Ceiling (ft) | Visibility (mi) |
|----------|-----------|--------------|-----------------|
| A        | Good      | > 1200       | > 4             |
|          | Bad       | < 800        | < 2             |
|          | Marginal  | Otherwise    | Otherwise       |
| B        | Good      | > 1500       | > 4             |
|          | Bad       | < 1000       | < 2             |
|          | Marginal  | Otherwise    | Otherwise       |
| C        | Good      | > 2500       | > 5             |
|          | Bad       | < 1500       | < 3             |
|          | Marginal  | Otherwise    | Otherwise       |
| D        | Good      | > 3000       | > 5             |
|          | Bad       | < 1800       | < 3             |
|          | Marginal  | Otherwise    | Otherwise       |

The frequencies of good, marginal, and bad days are tabulated for each corridor, each month of the 11-year period. For each corridor, the 12 monthly mean frequencies are calculated over the 11 years, and then the individual (year by year) monthly departures from the mean frequencies are calculated.

The monthly departures of good-day and bad-day frequencies ( $\pm\Delta G$  and  $\pm\Delta B$ , respectively) are the bases for the typicality calculations. A "net monthly departure" is defined,

$$\pm\Delta = \pm\Delta G - (\pm\Delta B)$$

where  $+\Delta$  indicates a better than average and  $-\Delta$  indicates a worse than average month. For example, if there are three fewer good days ( $\Delta G = -3$ ) and four more bad days ( $\Delta B = +4$ ) than the monthly mean, then,  $\Delta = -7$ , which would nominally indicate an atypically bad month. Or, if there are three fewer good days ( $\Delta G = -3$ ) and four fewer bad days ( $\Delta B = -4$ ), then  $\Delta = +1$ , which indicates a near-typical, slightly better than average month (that month having seven more marginal days than average). Table 2 gives the month-by-month values of  $\Delta$  for all corridors.

There can be considerable differences among the  $\Delta$ s for the four corridors in the same month--note February 1980. The average ( $\bar{\Delta}$ ) of the four  $\Delta$ s for that month ( $= -0.3$ ), taken alone, would indicate that February 1980 is "the most typical" February over the theater as a whole; but, as we see, this normal appearance results from the northern corridors (A,B) being abnormally bad, while the southern corridors (C,D) are abnormally good. To mitigate this pitfall, we also calculate the standard deviation ( $\sigma$ ) of the four corridor  $\Delta$ s each month, to combine with  $\bar{\Delta}$  in a joint measure of "typicality."

As a final measure of typicality, call it "T," we elect to give the corridor average departure ( $\bar{\Delta}$ ) twice the weight of the inter-corridor variability ( $\sigma$ ), and calculate

$$T = \sqrt{(2 \bar{\Delta}^2) + \sigma^2}.$$

Table 2

MONTHLY CORRIDOR DEPARTURES FROM THE MEAN OF GOOD-DAY/BAD-DAY FREQUENCIES ( $\Delta$ )

|      | January |       |       |       | February |       |       |       | March |      |       |      | April |      |      |       |
|------|---------|-------|-------|-------|----------|-------|-------|-------|-------|------|-------|------|-------|------|------|-------|
|      | A       | B     | C     | D     | A        | B     | C     | D     | A     | B    | C     | D    | A     | B    | C    | D     |
| 1973 | -15.6   | -19.4 | -14.5 | -7.7  | +9.1     | +2.4  | +6.4  | -5.2  | -0.3  | -4.2 | +4.4  | +1.6 | +5.2  | -0.1 | +4.5 | -2.7  |
| 1974 | +5.6    | +6.6  | +3.5  | -3.7  | +4.1     | +10.4 | +4.4  | -3.2  | +5.7  | +4.8 | -8.6  | -2.6 | +3.2  | +5.9 | +6.5 | +10.3 |
| 1975 | +16.4   | +16.6 | +12.5 | +4.3  | +7.1     | +0.4  | +10.4 | +8.8  | -1.3  | -1.2 | -0.6  | -7.4 | +0.8  | -6.1 | +1.5 | -2.7  |
| 1976 | +12.4   | +4.6  | -0.5  | -0.7  | -7.9     | -14.6 | -16.6 | -10.2 | +5.7  | -3.2 | -0.6  | +8.6 | +1.2  | +4.9 | +3.5 | +5.3  |
| 1977 | -13.6   | -11.4 | -4.5  | -7.7  | -3.9     | +7.4  | +10.4 | +6.8  | -1.3  | +0.2 | +0.4  | +0.6 | +2.2  | +2.9 | +3.5 | +0.3  |
| 1978 | -1.6    | +0.6  | +9.5  | +12.3 | -0.9     | +6.6  | -12.6 | -12.2 | +1.7  | +7.8 | +9.4  | -5.4 | -10.8 | -7.1 | -9.5 | -3.7  |
| 1979 | -2.6    | -10.4 | -1.5  | -2.7  | -12.9    | -5.6  | +0.4  | +9.8  | +0.7  | +0.8 | +3.4  | +0.6 | -4.8  | -6.1 | -5.5 | -7.7  |
| 1980 | -8.6    | +0.6  | -8.5  | +0.3  | +7.1     | +4.4  | -1.6  | +5.8  | -7.3  | -6.2 | -11.6 | -5.4 | +1.2  | +3.9 | -2.5 | -17.7 |
| 1981 | +5.4    | +0.6  | -4.5  | +0.3  | +10.9    | -2.6  | -8.6  | -3.2  | -4.3  | +1.8 | +5.4  | +6.6 | -0.8  | -6.1 | -5.5 | -17.3 |
| 1982 | -8.6    | -0.4  | -3.5  | -3.7  | -10.9    | -2.6  | -8.6  | -3.2  | +1.7  | +3.8 | +4.4  | +4.6 | +5.2  | +6.9 | +3.5 | +10.3 |
| 1983 | +22.4   | +18.6 | +12.5 | +9.3  | +13.1    | +8.4  | +2.4  | +2.8  | -1.3  | -4.2 | -5.6  | -7.4 | -0.8  | +0.9 | +0.5 | +1.3  |

|      | May  |      |      |      | June |      |       |      | July |      |       |      | August |       |       |      |
|------|------|------|------|------|------|------|-------|------|------|------|-------|------|--------|-------|-------|------|
|      | A    | B    | C    | D    | A    | B    | C     | D    | A    | B    | C     | D    | A      | B     | C     | D    |
| 1973 | +2.1 | +2.9 | +3.3 | +3.7 | +0.5 | +2.8 | +0.5  | -0.7 | +0.3 | +1.1 | -3.4  | -1.8 | +0.3   | +2.6  | -0.4  | +5.5 |
| 1974 | +0.1 | -0.1 | -4.7 | -6.3 | -0.2 | -0.2 | -1.5  | -0.7 | +0.3 | -0.9 | +1.6  | +0.2 | -0.7   | -0.4  | -2.4  | -5.5 |
| 1975 | +1.1 | +0.9 | -1.7 | +2.7 | +3.5 | +3.8 | +4.5  | +4.3 | +1.3 | +2.1 | +0.6  | +2.2 | +1.7   | +2.6  | +1.4  | -2.5 |
| 1976 | +3.1 | +0.9 | +8.3 | +0.7 | +2.5 | +4.8 | -15.5 | -3.7 | +2.3 | +0.1 | +0.6  | +0.2 | +1.7   | +3.6  | +7.6  | +2.5 |
| 1977 | +1.1 | -0.1 | -0.7 | +3.7 | -0.5 | -9.2 | -15.5 | -3.7 | +1.3 | +1.1 | +5.6  | +8.2 | -3.3   | -11.4 | -10.4 | -5.5 |
| 1978 | +1.1 | -7.1 | -9.7 | -8.3 | +1.5 | -1.2 | +6.5  | +2.3 | +1.3 | +0.9 | -0.4  | -1.8 | +0.7   | +2.6  | +5.6  | +1.5 |
| 1979 | +0.1 | +2.9 | +0.3 | +2.7 | -3.5 | -5.2 | +0.5  | +1.3 | -2.7 | -0.9 | -0.4  | -1.8 | -1.3   | +0.6  | +0.6  | -3.5 |
| 1980 | -1.9 | +0.9 | +2.3 | +0.7 | -3.5 | -2.2 | +0.5  | +1.3 | -7.7 | -5.9 | -10.4 | -6.8 | -2.3   | +1.4  | +3.6  | -2.5 |
| 1981 | -1.9 | +0.9 | +0.3 | +2.7 | -5.5 | -0.2 | +4.5  | +2.3 | -0.7 | -1.9 | -0.4  | -4.8 | -0.3   | -3.4  | -5.4  | +2.5 |
| 1982 | -3.9 | -1.1 | +3.3 | +2.7 | +1.5 | +3.8 | +2.5  | +3.3 | -2.3 | +4.1 | +3.6  | +1.2 | +1.7   | +1.6  | +4.6  | +1.5 |
| 1983 | -0.9 | -0.1 | -0.7 | -0.3 | +1.5 | +2.8 | +2.5  | -0.7 | +2.3 | +1.1 | +1.6  | +5.2 | +0.7   | +2.6  | -2.4  | +0.5 |

|      | September |      |      |       | October |       |       |       | November |       |       |       | December |       |      |       |
|------|-----------|------|------|-------|---------|-------|-------|-------|----------|-------|-------|-------|----------|-------|------|-------|
|      | A         | B    | C    | D     | A       | B     | C     | D     | A        | B     | C     | D     | A        | B     | C    | D     |
| 1973 | -1.1      | -0.1 | +3.7 | +8.2  | +7.6    | +0.4  | +4.6  | +2.3  | +6.6     | +9.0  | +10.3 | +4.3  | -2.7     | +3.5  | +5.1 | +3.6  |
| 1974 | +2.9      | +3.9 | -2.3 | -1.8  | +8.6    | -1.6  | -7.4  | -3.7  | +2.6     | +5.0  | +5.3  | +2.3  | +1.3     | +6.5  | +7.1 | -5.4  |
| 1975 | +6.9      | +2.9 | -4.3 | -3.8  | -5.4    | -7.6  | -6.4  | +0.3  | -10.4    | -10.0 | -11.7 | -4.7  | +6.3     | -0.5  | -3.9 | -12.4 |
| 1976 | -0.1      | -4.1 | -4.3 | -3.8  | -19.4   | -9.6  | -4.4  | -7.7  | +0.6     | -8.0  | -8.7  | -0.7  | +10.3    | -1.5  | -3.9 | -4.4  |
| 1977 | +1.9      | -1.1 | -5.3 | -5.8  | -15.4   | -7.6  | -12.4 | -11.7 | +12.6    | -12.0 | +12.3 | +12.3 | -5.7     | -0.5  | -7.9 | -5.4  |
| 1978 | -2.1      | -2.1 | +0.7 | +1.2  | -3.4    | -7.6  | -3.4  | -10.7 | -12.4    | -12.0 | -9.7  | -14.7 | -7.7     | -5.5  | -0.9 | +2.6  |
| 1979 | -1.1      | +1.9 | +0.7 | -4.8  | +4.6    | +3.4  | +3.6  | +11.3 | -10.4    | -2.0  | -3.7  | -7.7  | -0.7     | +4.5  | +7.1 | +12.6 |
| 1980 | -6.1      | -6.1 | -9.3 | -4.8  | +12.6   | +14.4 | +6.6  | +6.3  | -10.4    | -1.0  | +3.3  | +6.3  | +1.3     | +0.5  | +3.1 | +2.6  |
| 1981 | -3.1      | -1.1 | -3.3 | -3.8  | +3.6    | +5.4  | +6.6  | +7.3  | +5.6     | +7.0  | +6.3  | +4.3  | -3.7     | -13.5 | +7.9 | -6.4  |
| 1982 | -3.1      | -1.1 | +3.7 | -3.8  | -3.4    | +0.4  | -9.4  | -1.7  | +3.6     | +8.0  | +9.3  | +4.3  | -0.7     | +1.5  | +3.1 | +7.6  |
| 1983 | +4.9      | +6.9 | +7.7 | +14.2 | +13.6   | +10.4 | +13.6 | +8.3  | -4.4     | -8.0  | -12.7 | -5.7  | +2.3     | +7.5  | -0.9 | +4.6  |

The month having the smallest value of T is the "most typical." Several other ways of combining the two parameters were tried, resulting in only minor difference in the typicality rankings of the individual months. Table 3 gives the monthly value of  $\Delta$ ,  $\sigma$ , T, and rank; and Table 4 is a quick-look summary of the top-rank typical months.

To examine the seasonal nature of weather variability, a combined measure of spatial (intercorridor) and temporal (interannual) aviation-weather variability,  $\sigma$  (C, Y) was calculated and is graphed in Fig. 5. October through February are clearly the most variable months, meaning that it is least meaningful to define "typical" months among them.

### **TYPICAL SEASONS OF AVIATION WEATHER**

For possible use in studies of NATO-theater wars exceeding one month simulated duration, several periods of near-typical weather for two or more months are identified, as shown in Table 5.

### **ATYPICAL MONTHS OF AVIATION WEATHER**

A potentially useful by-product of this analysis is the identification of worst and best months for aviation activity. Testing the sensitivity to weather of battle simulation outcomes could be very important, especially in light of the very large year-to-year variability of flying weather. In the real world, the probability of a war occurring during a "near-typical" month of aviation weather is only about 0.20 from October through March, but is greater than 0.50 from April through September--see Fig. 6.

Table 6 summarizes the worst-month and best-month data for our 11-year database. These are the extremes; intermediate values of badness and goodness can be determined from Table 3.

Table 3

MONTHLY "TYPICALITY" PARAMETERS AND RANKINGS

| Year | January        |          |      |      | February       |          |      |      |
|------|----------------|----------|------|------|----------------|----------|------|------|
|      | $\bar{\Delta}$ | $\sigma$ | T    | Rank | $\bar{\Delta}$ | $\sigma$ | T    | Rank |
| 1973 | -14.3          | 4.9      | 29.0 | 10   | + 3.2          | 6.2      | 8.9  | 3    |
| 1974 | + 2.1          | 5.3      | 6.8  | 3    | + 3.9          | 5.6      | 9.6  | 4    |
| 1975 | +12.5          | 5.8      | 25.7 | 9    | + 6.7          | 4.4      | 14.1 | 8    |
| 1976 | + 4.0          | 6.1      | 10.1 | 5    | -12.3          | 4.0      | 24.9 | 11   |
| 1977 | - 9.3          | 4.0      | 19.0 | 8    | + 5.2          | 6.3      | 12.2 | 6    |
| 1978 | + 5.2          | 6.7      | 12.4 | 6    | - 8.1          | 5.5      | 17.1 | 10   |
| 1979 | - 2.6          | 2.8      | 5.9  | 2    | - 2.3          | 2.9      | 5.4  | 1    |
| 1980 | - 7.6          | 3.3      | 15.6 | 7    | - 0.3          | 10.1     | 10.1 | 5    |
| 1981 | + 0.5          | 4.0      | 4.1  | 1    | + 3.9          | 3.8      | 8.7  | 2    |
| 1982 | - 4.1          | 3.4      | 8.9  | 4    | - 6.3          | 4.1      | 13.3 | 7    |
| 1983 | +15.7          | 5.9      | 31.9 | 11   | + 6.7          | 5.1      | 14.3 | 9    |
| Year | March          |          |      |      | April          |          |      |      |
|      | $\bar{\Delta}$ | $\sigma$ | T    | Rank | $\bar{\Delta}$ | $\sigma$ | T    | Rank |
| 1973 | + 0.4          | 3.6      | 3.7  | 3    | + 1.7          | 3.8      | 5.1  | 3    |
| 1974 | + 1.1          | 6.6      | 7.0  | 6    | + 6.5          | 2.9      | 13.3 | 9    |
| 1975 | - 2.6          | 3.2      | 6.1  | 4    | - 2.0          | 3.2      | 5.1  | 3    |
| 1976 | + 2.6          | 5.5      | 7.6  | 8    | + 3.7          | 1.9      | 7.6  | 6    |
| 1977 | - 0.1          | 0.9      | 0.9  | 1    | + 2.2          | 1.4      | 4.6  | 2    |
| 1978 | + 3.4          | 6.7      | 9.5  | 9    | - 7.8          | 3.1      | 15.9 | 11   |
| 1979 | + 1.4          | 1.4      | 3.1  | 2    | - 6.0          | 1.2      | 12.1 | 7    |
| 1980 | - 7.6          | 2.8      | 15.5 | 11   | - 3.8          | 9.6      | 12.2 | 8    |
| 1981 | + 2.4          | 4.9      | 6.9  | 5    | - 1.3          | 6.2      | 6.7  | 5    |
| 1982 | + 3.6          | 1.3      | 7.3  | 7    | + 6.5          | 2.9      | 13.3 | 9    |
| 1983 | - 4.6          | 2.6      | 9.6  | 10   | + 0.5          | 0.9      | 1.3  | 1    |
| Year | May            |          |      |      | June           |          |      |      |
|      | $\bar{\Delta}$ | $\sigma$ | T    | Rank | $\bar{\Delta}$ | $\sigma$ | T    | Rank |
| 1973 | + 3.0          | 0.7      | 6.0  | 8    | + 0.8          | 1.5      | 2.2  | 2    |
| 1974 | - 2.8          | 3.2      | 6.4  | 9    | + 0.0          | 1.7      | 1.7  | 1    |
| 1975 | + 0.5          | 1.9      | 2.1  | 2    | - 1.2          | 5.8      | 6.3  | 8    |
| 1976 | + 3.3          | 3.5      | 7.5  | 10   | + 4.0          | 1.0      | 8.1  | 9    |
| 1977 | + 1.0          | 1.9      | 2.8  | 5    | - 7.2          | 6.6      | 15.8 | 11   |
| 1978 | - 6.0          | 4.9      | 13.0 | 11   | + 2.3          | 3.2      | 5.6  | 6    |
| 1979 | + 1.5          | 1.5      | 3.4  | 6    | + 4.0          | 2.8      | 8.5  | 10   |
| 1980 | + 0.5          | 1.8      | 2.1  | 2    | - 1.0          | 2.3      | 3.0  | 3    |
| 1981 | - 0.8          | 1.6      | 2.3  | 4    | + 0.3          | 4.3      | 4.3  | 5    |
| 1982 | + 0.3          | 3.4      | 3.5  | 7    | + 2.8          | 1.0      | 5.7  | 7    |
| 1983 | - 0.5          | 0.4      | 1.1  | 1    | + 1.5          | 1.6      | 3.4  | 4    |

Table 3--continued

| Year | July           |          |      |      | August         |          |      |      |
|------|----------------|----------|------|------|----------------|----------|------|------|
|      | $\bar{\Delta}$ | $\sigma$ | T    | Rank | $\bar{\Delta}$ | $\sigma$ | T    | Rank |
| 1973 | - 1.0          | 2.0      | 2.8  | 4    | + 1.9          | 2.8      | 4.7  | 5    |
| 1974 | + 0.3          | 1.0      | 1.2  | 1    | - 1.9          | 2.7      | 4.7  | 5    |
| 1975 | + 1.8          | 0.4      | 3.6  | 6    | + 0.1          | 2.4      | 2.4  | 2    |
| 1976 | + 0.8          | 1.0      | 1.9  | 3    | + 3.9          | 2.6      | 8.2  | 10   |
| 1977 | + 4.1          | 3.5      | 8.9  | 10   | - 7.7          | 3.9      | 15.9 | 11   |
| 1978 | - 0.2          | 1.3      | 1.4  | 2    | + 2.6          | 2.1      | 5.6  | 9    |
| 1979 | - 1.5          | 1.0      | 3.2  | 5    | - 0.9          | 2.0      | 2.7  | 3    |
| 1980 | - 7.7          | 1.9      | 15.5 | 11   | + 0.6          | 2.9      | 3.1  | 4    |
| 1981 | - 2.0          | 2.0      | 4.5  | 7    | - 1.7          | 3.5      | 4.9  | 7    |
| 1982 | + 2.8          | 1.3      | 5.7  | 9    | + 2.4          | 1.5      | 5.0  | 8    |
| 1983 | + 2.6          | 1.8      | 5.5  | 8    | + 0.4          | 2.1      | 2.2  | 1    |

| Year | September      |          |      |      | October        |          |      |      |
|------|----------------|----------|------|------|----------------|----------|------|------|
|      | $\bar{\Delta}$ | $\sigma$ | T    | Rank | $\bar{\Delta}$ | $\sigma$ | T    | Rank |
| 1973 | + 2.7          | 4.2      | 6.8  | 8    | + 3.7          | 3.1      | 8.0  | 2    |
| 1974 | + 4.9          | 2.1      | 10.0 | 9    | - 1.0          | 6.9      | 7.2  | 1    |
| 1975 | + 1.4          | 4.3      | 5.1  | 4    | - 4.8          | 3.5      | 10.2 | 4    |
| 1976 | - 3.1          | 2.0      | 6.5  | 7    | -10.3          | 6.5      | 21.6 | 8    |
| 1977 | - 2.6          | 3.7      | 6.4  | 6    | -11.8          | 3.2      | 23.8 | 10   |
| 1978 | - 0.6          | 1.8      | 2.2  | 1    | - 6.3          | 3.6      | 13.1 | 7    |
| 1979 | - 0.7          | 3.6      | 3.9  | 2    | + 5.7          | 3.8      | 12.0 | 6    |
| 1980 | - 6.6          | 1.9      | 13.3 | 10   | +12.0          | 3.9      | 24.3 | 11   |
| 1981 | - 2.8          | 1.2      | 5.7  | 5    | + 5.7          | 1.6      | 11.5 | 5    |
| 1982 | - 1.1          | 3.4      | 4.0  | 3    | - 3.5          | 4.2      | 8.2  | 3    |
| 1983 | + 8.4          | 4.0      | 17.3 | 11   | +11.5          | 2.6      | 23.1 | 9    |

| Year | November       |          |      |      | December       |          |      |      |
|------|----------------|----------|------|------|----------------|----------|------|------|
|      | $\bar{\Delta}$ | $\sigma$ | T    | Rank | $\bar{\Delta}$ | $\sigma$ | T    | Rank |
| 1973 | + 7.6          | 2.7      | 15.4 | 7    | + 2.4          | 3.5      | 5.9  | 2    |
| 1974 | + 3.8          | 1.6      | 7.8  | 1    | + 2.4          | 5.8      | 7.5  | 6    |
| 1975 | - 9.2          | 3.1      | 18.7 | 9    | - 2.6          | 7.8      | 9.4  | 8    |
| 1976 | - 4.2          | 4.8      | 9.7  | 3    | + 0.1          | 6.9      | 6.9  | 4    |
| 1977 | +12.3          | 0.2      | 24.6 | 11   | - 4.9          | 3.1      | 10.3 | 9    |
| 1978 | -12.2          | 2.0      | 24.5 | 10   | - 2.9          | 4.6      | 7.4  | 5    |
| 1979 | - 6.0          | 3.8      | 12.6 | 5    | + 5.9          | 5.5      | 13.0 | 10   |
| 1980 | + 3.6          | 3.3      | 7.9  | 2    | + 1.9          | 1.2      | 4.0  | 1    |
| 1981 | + 5.8          | 1.2      | 11.7 | 4    | - 7.9          | 4.1      | 16.3 | 11   |
| 1982 | + 6.3          | 2.8      | 12.9 | 6    | + 2.1          | 4.2      | 5.9  | 2    |
| 1983 | - 7.7          | 3.7      | 15.8 | 8    | + 3.4          | 3.6      | 7.7  | 7    |



Table 4

SUMMARY OF TOP-RANK TYPICAL MONTHS FOR AVIATION WEATHER

| Month     | 1st Rank |                |          | 2nd Rank |                |          | 3rd Rank |                |          |
|-----------|----------|----------------|----------|----------|----------------|----------|----------|----------------|----------|
|           | Year     | $\bar{\Delta}$ | $\sigma$ | Year     | $\bar{\Delta}$ | $\sigma$ | Year     | $\bar{\Delta}$ | $\sigma$ |
| January   | 1981     | + 0.5          | 4.0      | 1979     | - 2.6          | 2.8      | 1974     | + 2.1          | 5.3      |
| February  | 1979     | - 2.3          | 2.9      | 1981     | + 3.9          | 3.8      | 1973     | + 3.2          | 6.2      |
| March     | 1977     | - 0.1          | 0.9      | 1979     | + 1.4          | 1.4      | 1973     | + 0.4          | 3.6      |
| April     | 1983     | + 0.5          | 0.9      | 1977     | + 2.2          | 1.4      | 1975     | - 2.0          | 3.2      |
| May       | 1983     | - 0.5          | 0.4      | 1980     | + 0.5          | 1.8      | 1975     | + 0.5          | 1.9      |
| June      | 1974     | + 0.0          | 1.7      | 1973     | + 0.8          | 1.5      | 1980     | - 1.0          | 2.3      |
| July      | 1974     | + 0.3          | 1.0      | 1978     | - 0.2          | 1.3      | 1976     | + 0.8          | 1.0      |
| August    | 1983     | + 0.4          | 2.1      | 1975     | + 0.1          | 2.4      | 1979     | - 0.9          | 2.0      |
| September | 1978     | - 0.6          | 1.8      | 1979     | - 0.7          | 3.6      | 1982     | - 1.1          | 3.4      |
| October   | 1974     | - 1.0          | 6.9      | 1973     | + 3.7          | 3.1      | 1982     | - 3.5          | 4.2      |
| November  | 1974     | + 3.8          | 1.6      | 1980     | + 3.6          | 3.3      | 1976     | - 4.2          | 4.8      |
| December  | 1980     | + 1.9          | 1.2      | 1982     | + 2.1          | 4.2      | 1973     | + 2.4          | 3.5      |

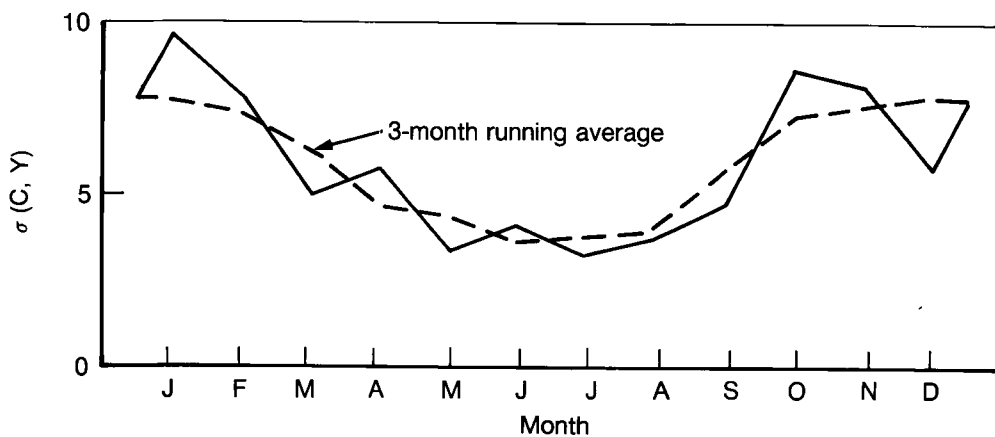


Fig. 5 -- Monthly values of a combined space-time measure of the variability of aviation weather in central Europe over the years 1973-1983. ( $\sigma(C, Y)$  is standard deviation of the net monthly departures from average of aviation weather (good-day/bad-day frequencies) taken over all corridors and years)

Table 5

NEAR-TYPICAL SEASONS (TWO OR MORE MONTHS) OF AVIATION WEATHER

| Season        | Year          | Month | Rank | $\bar{\Delta}$ | $\sigma$ | Season        | Year | Month | Rank  | $\bar{\Delta}$ | $\sigma$ |
|---------------|---------------|-------|------|----------------|----------|---------------|------|-------|-------|----------------|----------|
| Winter        | 1973          | Dec   | 2    | + 2.4          | 3.5      | Spring-Summer | 1983 | Apr   | 1     | + 0.5          | 0.9      |
|               | 1974          | Jan   | 3    | + 2.1          | 5.3      |               | May  | 1     | - 0.5 | 0.4            |          |
|               |               | Feb   | 4    | + 3.9          | 5.6      |               | Jun  | 4     | + 1.5 | 1.6            |          |
|               | 1976          | Nov   | 3    | - 4.2          | 4.8      | Summer        | 1973 | Jun   | 2     | + 0.8          | 1.5      |
|               |               | Dec   | 4    | + 0.1          | 6.9      |               | Jul  | 4     | - 1.0 | 2.0            |          |
|               | 1979          | Jan   | 2    | - 2.6          | 2.8      | 1974          | Jun  | 1     | + 0.0 | 1.7            |          |
|               |               | Feb   | 1    | - 2.3          | 2.9      |               | Jul  | 1     | + 0.3 | 1.0            |          |
|               |               | Mar   | 2    | + 1.4          | 1.4      |               | 1980 | May   | 2     | + 0.5          | 1.8      |
|               | 1980          | Nov   | 2    | + 3.6          | 3.3      | Jun           |      | 3     | - 1.0 | 2.3            |          |
|               |               | Dec   | 1    | + 1.9          | 1.2      | Summer-Fall   |      | 1975  | Aug   | 2              | + 0.1    |
|               | 1981          | Jan   | 1    | + 0.5          | 4.0      |               |      | Sep   | 4     | + 1.4          | 4.3      |
|               |               | Feb   | 2    | + 3.9          | 3.8      |               | Oct  | 4     | - 4.8 | 3.5            |          |
|               | Winter-Spring | 1973  | Feb  | 3              | + 3.2    | 6.2           | 1979 | Aug   | 3     | - 0.9          | 2.0      |
|               |               |       | Mar  | 3              | + 0.4    | 3.6           |      | Sep   | 2     | - 0.7          | 3.6      |
| Apr           |               |       | 3    | + 1.7          | 3.8      | Fall          |      | 1982  | Sep   | 3              | - 1.1    |
| Spring        | 1977          | Mar   | 1    | - 0.1          | 0.9      |               | Oct  | 3     | - 3.5 | 4.2            |          |
|               |               | Apr   | 2    | + 2.2          | 1.4      | Fall-Winter   | 1974 | Oct   | 1     | - 1.0          | 6.9      |
| Spring-Summer | 1975          | Mar   | 4    | - 2.6          | 3.2      |               | Nov  | 1     | + 3.8 | 1.6            |          |
|               |               | Apr   | 3    | - 2.0          | 3.2      |               |      |       |       |                |          |
|               |               | May   | 2    | + 0.5          | 1.9      |               |      |       |       |                |          |

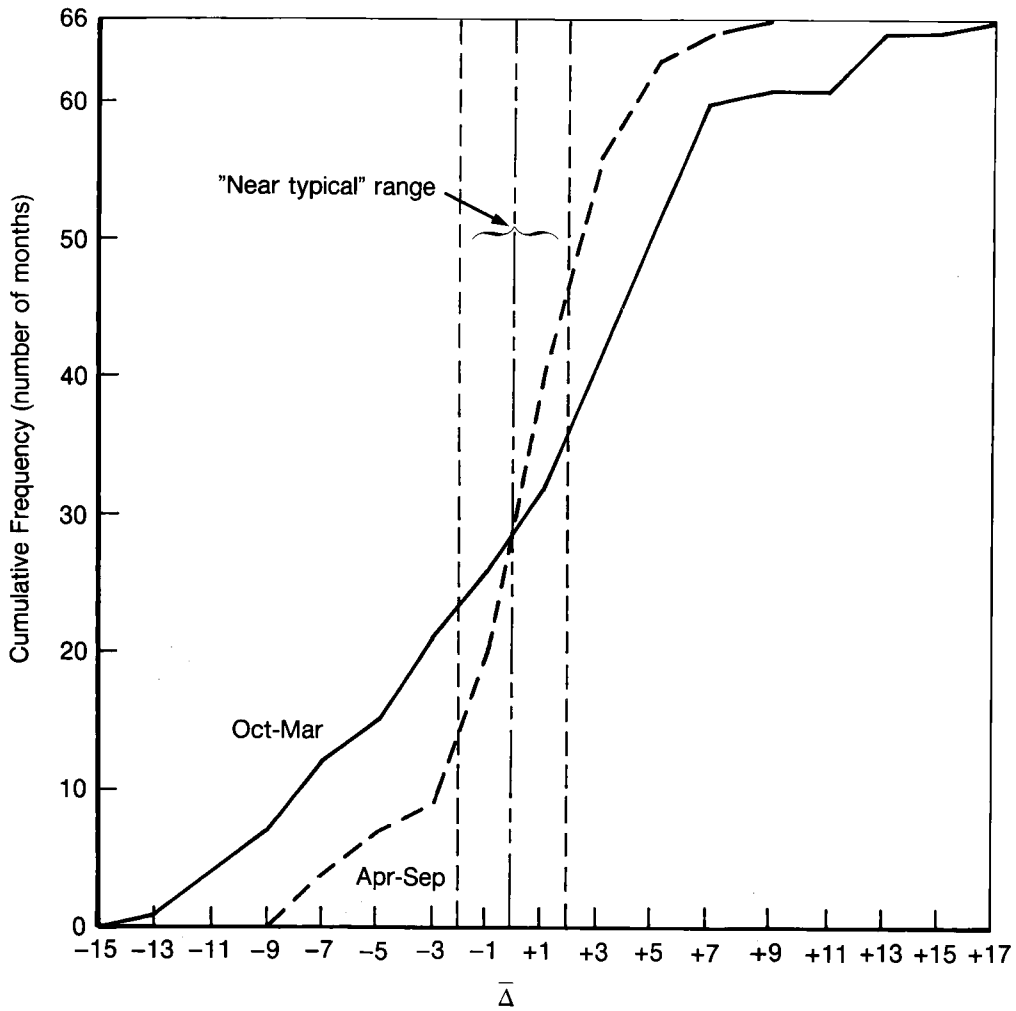


Fig. 6 -- Cumulative frequencies of net monthly departures,  $\bar{\Delta}$ , of aviation weather for winter (October through March) and summer (April through September) half-years

Table 6

SUMMARY OF WORST AND BEST MONTH DATA

| Month     | Worst |      |                |          | Best   |      |                |          |
|-----------|-------|------|----------------|----------|--------|------|----------------|----------|
|           | Year  | Rank | $\bar{\Delta}$ | $\sigma$ | Year   | Rank | $\bar{\Delta}$ | $\sigma$ |
| January   | 1973  | 10   | -14.3          | 4.9      | 1983   | 11   | +15.7          | 5.9      |
| February  | 1976  | 11   | -12.3          | 4.0      | 1983   | 9    | + 6.7          | 5.1      |
| March     | 1980  | 11   | - 7.6          | 2.8      | 1978   | 9    | + 3.4          | 6.7      |
| April     | 1978  | 11   | - 7.8          | 3.1      | 74, 82 | 9    | + 6.5          | 2.9      |
| May       | 1978  | 11   | - 6.0          | 4.9      | 1976   | 10   | + 3.3          | 3.5      |
| June      | 1977  | 11   | - 7.2          | 6.6      | 1979   | 10   | + 4.0          | 2.8      |
| July      | 1980  | 11   | - 7.7          | 1.9      | 1977   | 10   | + 4.1          | 3.5      |
| August    | 1977  | 11   | - 7.7          | 3.9      | 1976   | 10   | + 3.9          | 2.6      |
| September | 1980  | 10   | - 6.6          | 1.9      | 1983   | 11   | + 8.4          | 4.0      |
| October   | 1977  | 10   | -11.8          | 3.2      | 1980   | 11   | +12.0          | 3.9      |
| November  | 1978  | 10   | -12.2          | 2.0      | 1977   | 11   | +12.3          | 0.2      |
| December  | 1981  | 11   | - 7.9          | 4.1      | 1979   | 10   | + 5.9          | 5.5      |

### III. MONTHS HAVING TYPICAL PRECIPITATION FREQUENCIES

The same 11-year weather observational data as for the aviation weather analysis above was used to analyze the month-by-month, corridor-by-corridor precipitation and snowfall frequencies. (Precipitation amounts were not used because of the large uncertainty as to the quantity and regularity of such data in the database.)

Table 7 shows the average monthly frequencies of precipitation (all types) and snowfall (only). There is a pronounced annual cycle, with precipitation occurring about twice as often in winter as in summer. The frequency of rain (the difference between precipitation and snowfall frequencies) is nearly constant throughout the year. Winter precipitation is about 40 percent snowfall--more in the higher elevations of the south (corridors C and D) than over the plains of the north.

The large year-to-year variability of precipitation frequency is evident in Tables 8 and 9, which give the monthly percent departures from the 11-year average frequencies. Nearly half (45 percent) of the months when all corridors are combined, however, have precipitation frequencies within 20 percent of the average.

Table 10 provides a quick-look summary of the most typical months in terms of precipitation and snowfall frequencies.

Table 7

11-YEAR AVERAGE MONTHLY AND SEASONAL FREQUENCIES  
OF PRECIPITATION AND SNOWFALL (1973-1983)

| Month                    | Corridors |      |      |      |      |
|--------------------------|-----------|------|------|------|------|
|                          | A         | B    | C    | D    | All  |
| <i>All Precipitation</i> |           |      |      |      |      |
| January                  | 0.19      | 0.21 | 0.22 | 0.27 | 0.22 |
| February                 | 0.16      | 0.20 | 0.19 | 0.19 | 0.19 |
| March                    | 0.17      | 0.18 | 0.17 | 0.17 | 0.17 |
| April                    | 0.13      | 0.15 | 0.16 | 0.19 | 0.16 |
| May                      | 0.11      | 0.13 | 0.13 | 0.12 | 0.12 |
| June                     | 0.09      | 0.11 | 0.09 | 0.12 | 0.10 |
| July                     | 0.09      | 0.09 | 0.09 | 0.12 | 0.10 |
| August                   | 0.07      | 0.07 | 0.08 | 0.09 | 0.08 |
| September                | 0.10      | 0.09 | 0.07 | 0.09 | 0.09 |
| October                  | 0.13      | 0.12 | 0.14 | 0.13 | 0.13 |
| November                 | 0.16      | 0.16 | 0.17 | 0.21 | 0.17 |
| December                 | 0.21      | 0.21 | 0.24 | 0.24 | 0.22 |
| November-February        | 0.18      | 0.19 | 0.20 | 0.23 | 0.20 |
| May-August               | 0.09      | 0.10 | 0.10 | 0.11 | 0.10 |
| <i>Snowfall Only</i>     |           |      |      |      |      |
| January                  | 0.06      | 0.07 | 0.11 | 0.16 | 0.10 |
| February                 | 0.07      | 0.09 | 0.10 | 0.12 | 0.10 |
| March                    | 0.03      | 0.03 | 0.05 | 0.07 | 0.04 |
| April                    | 0.01      | 0.01 | 0.03 | 0.06 | 0.03 |
| May                      | --        | --   | --   | 0.01 | --   |
| June                     | --        | --   | --   | --   | --   |
| July                     | --        | --   | --   | --   | --   |
| August                   | --        | --   | --   | --   | --   |
| September                | --        | --   | --   | --   | --   |
| October                  | --        | --   | --   | 0.01 | --   |
| November                 | 0.01      | 0.02 | 0.05 | 0.08 | 0.04 |
| December                 | 0.05      | 0.06 | 0.10 | 0.13 | 0.09 |
| November-February        | 0.05      | 0.06 | 0.09 | 0.12 | 0.08 |

Table 8

MONTHLY PERCENT DEPARTURES OF PRECIPITATION FREQUENCY  
FROM 11-YEAR AVERAGE (1973-1983)

| Month | Year | Corridors |      |      |      |      | Typicality Rank |
|-------|------|-----------|------|------|------|------|-----------------|
|       |      | A         | B    | C    | D    | All  |                 |
| Jan   | 1973 | - 20      | - 1  | - 24 | - 15 | - 15 | 5               |
|       | 1974 | - 35      | - 14 | - 4  | - 28 | - 20 | 6               |
|       | 1975 | - 29      | - 33 | - 17 | - 42 | - 31 | 11              |
|       | 1976 | - 7       | + 22 | + 39 | + 56 | + 30 | 10              |
|       | 1977 | + 37      | + 19 | - 1  | - 8  | + 10 | 3               |
|       | 1978 | + 13      | - 14 | - 41 | - 31 | - 20 | 6               |
|       | 1979 | + 26      | + 42 | + 3  | + 17 | + 21 | 8               |
|       | 1980 | - 8       | - 9  | + 3  | + 20 | + 3  | 1               |
|       | 1981 | + 37      | + 19 | + 32 | + 16 | + 26 | 9               |
|       | 1982 | - 13      | - 40 | - 9  | + 9  | - 12 | 4               |
| 1983  | - 1  | + 8       | + 19 | + 7  | + 8  | 2    |                 |
| Feb   | 1973 | + 45      | + 24 | + 21 | + 53 | + 35 | 9               |
|       | 1974 | - 33      | - 37 | + 9  | + 18 | - 10 | 2               |
|       | 1975 | - 71      | - 54 | - 49 | - 50 | - 55 | 11              |
|       | 1976 | - 37      | - 30 | - 42 | - 44 | - 39 | 10              |
|       | 1977 | + 35      | + 6  | + 16 | + 30 | + 21 | 4               |
|       | 1978 | + 19      | + 30 | + 23 | + 21 | + 23 | 5               |
|       | 1979 | + 5       | + 23 | + 9  | + 16 | + 14 | 3               |
|       | 1980 | + 5       | + 17 | - 21 | - 25 | - 6  | 1               |
|       | 1981 | + 23      | + 26 | + 35 | + 16 | + 25 | 6               |
|       | 1982 | - 14      | - 35 | - 38 | - 45 | - 34 | 8               |
| 1983  | + 22 | + 30      | + 37 | + 10 | + 25 | 6    |                 |
| Mar   | 1973 | - 53      | - 31 | - 41 | - 14 | - 35 | 9               |
|       | 1974 | - 61      | - 57 | - 23 | - 50 | - 48 | 11              |
|       | 1975 | - 15      | - 6  | + 25 | + 42 | + 11 | 3               |
|       | 1976 | - 18      | - 13 | - 25 | - 54 | - 27 | 6               |
|       | 1977 | - 20      | - 25 | - 25 | - 16 | - 22 | 5               |
|       | 1978 | + 50      | + 9  | + 1  | + 27 | + 21 | 4               |
|       | 1979 | + 50      | + 48 | + 41 | + 39 | + 45 | 10              |
|       | 1980 | - 23      | - 19 | + 4  | + 7  | - 8  | 2               |
|       | 1981 | + 47      | + 48 | + 13 | - 4  | + 27 | 6               |
|       | 1982 | + 39      | + 40 | + 28 | + 20 | + 32 | 8               |
| 1983  | + 3  | + 7       | + 2  | + 3  | + 4  | 1    |                 |
| Apr   | 1973 | + 9       | + 23 | + 9  | + 2  | + 10 | 2               |
|       | 1974 | - 72      | - 65 | - 64 | - 49 | - 61 | 10              |
|       | 1975 | + 9       | + 20 | + 4  | - 18 | + 3  | 1               |
|       | 1976 | - 56      | - 50 | - 62 | - 36 | - 50 | 8               |
|       | 1977 | + 79      | + 25 | + 29 | + 38 | + 41 | 6               |
|       | 1978 | - 44      | - 60 | - 55 | - 49 | - 52 | 9               |
|       | 1979 | + 42      | + 14 | + 15 | + 46 | + 30 | 4               |
|       | 1980 | + 3       | + 9  | + 38 | + 72 | + 34 | 5               |
|       | 1981 | - 66      | - 36 | - 20 | - 59 | - 45 | 7               |
|       | 1982 | + 45      | + 87 | + 77 | + 42 | - 62 | 11              |
| 1983  | + 51 | + 34      | + 28 | + 11 | + 29 | 3    |                 |



Table 8--continued

| Month | Year | Corridors |       |       |      |       | All | Typicality Rank |
|-------|------|-----------|-------|-------|------|-------|-----|-----------------|
|       |      | A         | B     | C     | D    |       |     |                 |
| May   | 1973 | - 19      | - 17  | - 23  | - 15 | - 18  | 3   |                 |
|       | 1974 | - 23      | + 5   | + 7   | + 34 | + 6   | 2   |                 |
|       | 1975 | - 34      | - 42  | - 26  | - 25 | - 32  | 7   |                 |
|       | 1976 | - 10      | - 22  | - 45  | - 19 | - 25  | 5   |                 |
|       | 1977 | - 54      | - 40  | - 45  | - 54 | - 48  | 9   |                 |
|       | 1978 | - 59      | 0     | + 45  | + 79 | + 18  | 3   |                 |
|       | 1979 | - 11      | - 2   | - 43  | - 49 | - 26  | 6   |                 |
|       | 1980 | - 61      | - 67  | - 51  | - 27 | - 51  | 10  |                 |
|       | 1981 | - 17      | - 21  | + 22  | + 21 | + 2   | 1   |                 |
|       | 1982 | + 235     | + 165 | + 93  | + 42 | + 132 | 11  |                 |
| 1983  | + 53 | + 39      | + 65  | + 12  | + 42 | 8     |     |                 |
| Jun   | 1973 | - 35      | - 45  | - 18  | + 2  | - 23  | 8   |                 |
|       | 1974 | - 11      | + 19  | + 18  | + 23 | + 13  | 4   |                 |
|       | 1975 | - 57      | - 45  | + 15  | + 31 | - 12  | 3   |                 |
|       | 1976 | - 49      | - 49  | - 45  | - 55 | - 50  | 10  |                 |
|       | 1977 | - 23      | - 5   | + 72  | + 2  | + 11  | 2   |                 |
|       | 1978 | - 2       | + 2   | + 1   | - 5  | - 1   | 1   |                 |
|       | 1979 | - 25      | - 19  | - 24  | + 1  | - 16  | 6   |                 |
|       | 1980 | + 57      | + 39  | + 1   | - 13 | + 19  | 7   |                 |
|       | 1981 | + 70      | + 29  | 0     | - 27 | + 15  | 5   |                 |
|       | 1982 | + 95      | + 85  | + 36  | + 66 | + 71  | 11  |                 |
| 1983  | - 20 | - 10      | - 56  | - 26  | - 27 | 9     |     |                 |
| Jul   | 1973 | + 7       | + 5   | + 3   | - 14 | - 1   | 1   |                 |
|       | 1974 | + 50      | + 38  | + 47  | + 40 | + 43  | 8   |                 |
|       | 1975 | + 1       | - 47  | - 56  | - 15 | - 28  | 5   |                 |
|       | 1976 | - 52      | - 39  | - 46  | - 9  | - 34  | 7   |                 |
|       | 1977 | + 14      | + 26  | - 25  | - 49 | - 12  | 3   |                 |
|       | 1978 | - 1       | + 13  | - 4   | + 18 | + 7   | 2   |                 |
|       | 1979 | + 44      | + 18  | - 19  | + 9  | + 12  | 3   |                 |
|       | 1980 | + 69      | + 110 | + 164 | + 94 | + 108 | 11  |                 |
|       | 1981 | + 2       | + 17  | + 37  | + 51 | + 29  | 6   |                 |
|       | 1982 | - 70      | - 75  | - 45  | - 48 | - 58  | 9   |                 |
| 1983  | - 65 | - 65      | - 55  | - 76  | - 66 | 10    |     |                 |
| Aug   | 1973 | - 34      | - 51  | - 39  | - 56 | - 46  | 10  |                 |
|       | 1974 | - 9       | - 6   | + 14  | - 16 | - 5   | 2   |                 |
|       | 1975 | - 32      | - 41  | + 21  | + 31 | - 3   | 1   |                 |
|       | 1976 | - 55      | - 24  | - 42  | - 19 | - 34  | 9   |                 |
|       | 1977 | + 53      | + 58  | + 77  | + 81 | + 68  | 11  |                 |
|       | 1978 | - 2       | + 23  | + 7   | + 19 | + 12  | 6   |                 |
|       | 1979 | + 38      | + 32  | - 12  | + 17 | + 18  | 7   |                 |
|       | 1980 | + 81      | + 22  | - 36  | - 30 | + 6   | 3   |                 |
|       | 1981 | + 10      | + 37  | + 40  | - 46 | + 7   | 4   |                 |
|       | 1982 | + 8       | - 11  | - 23  | - 3  | - 7   | 4   |                 |
| 1983  | - 57 | - 38      | - 6   | + 21  | - 18 | 7     |     |                 |

Table 8--continued

| Month | Year | Corridors |       |       |       |       | Typicality Rank |
|-------|------|-----------|-------|-------|-------|-------|-----------------|
|       |      | A         | B     | C     | D     | All   |                 |
| Sep   | 1973 | + 8       | + 13  | - 25  | - 26  | - 6   | 6               |
|       | 1974 | + 9       | + 16  | 0     | - 27  | 0     | 1               |
|       | 1975 | - 31      | - 25  | - 23  | - 51  | - 33  | 9               |
|       | 1976 | 0         | + 16  | + 16  | + 58  | + 22  | 8               |
|       | 1977 | - 8       | - 5   | + 5   | + 5   | - 1   | 2               |
|       | 1978 | + 141     | + 122 | + 89  | + 49  | + 102 | 11              |
|       | 1979 | + 3       | - 40  | - 12  | + 31  | - 4   | 3               |
|       | 1980 | - 24      | - 21  | + 19  | - 15  | - 12  | 7               |
|       | 1981 | - 22      | - 14  | + 16  | + 42  | + 4   | 3               |
|       | 1982 | - 80      | - 65  | - 64  | - 59  | - 68  | 10              |
|       | 1983 | + 4       | + 3   | - 21  | - 8   | - 5   | 5               |
| Oct   | 1973 | - 8       | + 17  | - 20  | - 15  | - 7   | 2               |
|       | 1974 | + 63      | + 97  | + 142 | + 122 | + 106 | 11              |
|       | 1975 | - 40      | - 5   | - 13  | - 16  | - 19  | 6               |
|       | 1976 | + 9       | - 27  | - 34  | - 8   | - 15  | 4               |
|       | 1977 | - 51      | - 45  | - 35  | - 32  | - 41  | 8               |
|       | 1978 | - 14      | - 23  | - 12  | + 1   | - 12  | 3               |
|       | 1979 | - 48      | - 54  | - 61  | - 65  | - 57  | 10              |
|       | 1980 | + 15      | - 18  | - 8   | + 6   | - 1   | 1               |
|       | 1981 | + 51      | + 50  | + 48  | + 66  | + 53  | 9               |
|       | 1982 | + 16      | + 22  | + 35  | - 14  | + 15  | 4               |
|       | 1983 | + 7       | - 13  | - 42  | - 46  | - 24  | 7               |
| Nov   | 1973 | + 14      | - 1   | + 8   | + 47  | + 19  | 5               |
|       | 1974 | + 10      | + 14  | + 3   | - 9   | + 4   | 2               |
|       | 1975 | - 46      | - 25  | - 19  | - 19  | - 27  | 6               |
|       | 1976 | 0         | + 21  | + 21  | - 4   | + 8   | 3               |
|       | 1977 | + 24      | + 31  | + 66  | + 40  | + 41  | 11              |
|       | 1978 | - 13      | - 22  | - 43  | - 29  | - 27  | 6               |
|       | 1979 | - 3       | - 32  | - 19  | + 38  | - 1   | 1               |
|       | 1980 | + 29      | + 27  | + 16  | - 8   | + 15  | 4               |
|       | 1981 | + 19      | + 35  | + 46  | + 48  | + 38  | 10              |
|       | 1982 | - 11      | - 33  | - 47  | - 47  | - 36  | 9               |
|       | 1983 | - 26      | - 14  | - 34  | - 56  | - 34  | 8               |
| Dec   | 1973 | + 2       | + 5   | - 8   | - 1   | - 1   | 1               |
|       | 1974 | + 23      | + 38  | + 28  | + 66  | + 40  | 10              |
|       | 1975 | - 22      | - 34  | - 40  | - 28  | - 31  | 8               |
|       | 1976 | - 33      | - 36  | 0     | + 5   | - 15  | 4               |
|       | 1977 | - 30      | - 13  | - 17  | - 12  | - 18  | 6               |
|       | 1978 | + 40      | + 11  | + 5   | - 16  | + 9   | 3               |
|       | 1979 | + 38      | + 17  | + 16  | 0     | + 17  | 5               |
|       | 1980 | + 17      | + 3   | + 1   | + 10  | + 7   | 2               |
|       | 1981 | + 10      | + 52  | + 50  | + 60  | + 44  | 11              |
|       | 1982 | - 35      | - 34  | + 5   | - 25  | - 21  | 7               |
|       | 1983 | - 9       | - 11  | - 41  | - 60  | - 32  | 9               |

Table 9

MONTHLY PERCENT DEPARTURES OF SNOWFALL FREQUENCY  
FROM 11-YEAR AVERAGE  
(November through February, 1973-1983)

| Month | Year | Corridors |       |       |       |       | Typicality Rank |
|-------|------|-----------|-------|-------|-------|-------|-----------------|
|       |      | A         | B     | C     | D     | All   |                 |
| Nov   | 1973 | + 144     | + 54  | + 32  | + 66  | + 68  | 9               |
|       | 1974 | - 100     | - 96  | - 55  | - 15  | - 51  | 6               |
|       | 1975 | - 64      | - 61  | - 34  | - 65  | - 56  | 7               |
|       | 1976 | - 50      | - 71  | - 15  | - 15  | - 26  | 3               |
|       | 1977 | - 64      | - 4   | + 24  | + 83  | + 24  | 2               |
|       | 1978 | + 196     | + 108 | - 27  | + 1   | + 19  | 1               |
|       | 1979 | - 95      | - 92  | - 57  | - 32  | - 45  | 5               |
|       | 1980 | + 156     | + 324 | + 148 | + 93  | + 126 | 11              |
|       | 1981 | - 57      | - 26  | + 85  | + 47  | + 65  | 8               |
|       | 1982 | - 96      | - 100 | - 96  | - 88  | - 93  | 10              |
|       | 1983 | + 28      | - 38  | - 6   | - 76  | - 32  | 4               |
| Dec   | 1973 | + 13      | + 21  | - 2   | + 17  | + 11  | 2               |
|       | 1974 | - 88      | - 71  | - 40  | + 10  | - 33  | 4               |
|       | 1975 | - 94      | - 80  | - 34  | - 24  | - 47  | 6               |
|       | 1976 | + 49      | + 69  | + 65  | + 31  | + 50  | 7               |
|       | 1977 | - 70      | - 89  | - 68  | - 17  | - 52  | 8               |
|       | 1978 | + 145     | + 43  | - 29  | - 32  | + 8   | 1               |
|       | 1979 | - 23      | - 49  | - 23  | - 33  | - 31  | 3               |
|       | 1980 | - 7       | + 74  | + 49  | + 26  | + 36  | 5               |
|       | 1981 | + 218     | + 254 | + 169 | + 143 | + 181 | 11              |
|       | 1982 | - 72      | - 94  | - 56  | - 55  | - 64  | 10              |
|       | 1983 | - 70      | - 79  | - 30  | - 67  | - 58  | 9               |
| Jan   | 1973 | - 42      | - 74  | - 39  | 0     | - 30  | 5               |
|       | 1974 | - 96      | - 95  | - 76  | - 77  | - 83  | 8               |
|       | 1975 | - 94      | - 96  | - 85  | - 77  | - 85  | 10              |
|       | 1976 | - 25      | - 35  | + 11  | - 1   | - 8   | 2               |
|       | 1977 | + 21      | + 48  | + 36  | + 11  | + 26  | 4               |
|       | 1978 | - 5       | - 46  | - 20  | - 13  | - 19  | 3               |
|       | 1979 | + 201     | + 282 | + 71  | + 69  | + 127 | 11              |
|       | 1980 | + 60      | + 39  | + 39  | + 58  | + 50  | 6               |
|       | 1981 | + 73      | + 101 | + 111 | + 61  | + 83  | 8               |
|       | 1982 | - 2       | - 54  | + 6   | + 16  | - 1   | 1               |
|       | 1983 | - 92      | - 71  | - 55  | - 46  | - 60  | 7               |
| Feb   | 1973 | - 46      | - 36  | + 29  | + 87  | + 16  | 1               |
|       | 1974 | - 92      | - 95  | - 30  | - 6   | - 50  | 5               |
|       | 1975 | - 93      | - 90  | - 67  | - 59  | - 75  | 9               |
|       | 1976 | - 48      | - 27  | - 24  | - 36  | - 33  | 3               |
|       | 1977 | - 15      | - 79  | - 68  | - 60  | - 58  | 6               |
|       | 1978 | + 127     | + 143 | + 87  | + 78  | + 106 | 11              |
|       | 1979 | - 91      | + 115 | + 12  | - 8   | + 46  | 4               |
|       | 1980 | + 5       | - 17  | - 63  | - 43  | - 32  | 2               |
|       | 1981 | + 52      | + 70  | + 76  | + 39  | + 59  | 8               |
|       | 1982 | - 84      | - 78  | - 52  | - 30  | - 58  | 6               |
|       | 1983 | + 102     | + 92  | + 98  | + 39  | + 79  | 10              |

Table 10

SUMMARY OF TOP-RANK TYPICAL MONTHS FOR  
PRECIPITATION AND SNOWFALL FREQUENCY

| Month                    | 1st Rank |     | 2nd Rank |     | 3rd Rank |     |
|--------------------------|----------|-----|----------|-----|----------|-----|
|                          | Year     | % Δ | Year     | % Δ | Year     | % Δ |
| <i>All Precipitation</i> |          |     |          |     |          |     |
| January                  | 1980     | + 3 | 1983     | + 8 | 1977     | +10 |
| February                 | 1980     | - 6 | 1974     | -10 | 1979     | +14 |
| March                    | 1983     | + 4 | 1980     | - 8 | 1975     | +11 |
| April                    | 1975     | + 3 | 1973     | +10 | 1983     | +29 |
| May                      | 1981     | + 2 | 1974     | + 6 | 1973     | -18 |
|                          |          |     |          |     | 1978     | +18 |
| June                     | 1978     | - 1 | 1977     | +11 | 1975     | -12 |
| July                     | 1973     | - 1 | 1978     | + 7 | 1977     | -12 |
|                          |          |     |          |     | 1979     | +12 |
| August                   | 1975     | - 3 | 1974     | - 5 | 1980     | + 6 |
| September                | 1974     | - 0 | 1977     | - 1 | 1979     | - 4 |
|                          |          |     |          |     | 1981     | + 4 |
| October                  | 1980     | - 1 | 1973     | - 7 | 1978     | -12 |
| November                 | 1979     | - 1 | 1974     | + 4 | 1976     | + 8 |
| December                 | 1973     | - 1 | 1980     | + 7 | 1978     | + 9 |
| <i>Snowfall Only</i>     |          |     |          |     |          |     |
| January                  | 1982     | - 1 | 1976     | - 8 | 1978     | -19 |
| February                 | 1973     | +16 | 1980     | -32 | 1976     | -33 |
| November                 | 1978     | +19 | 1977     | +24 | 1976     | -26 |
| December                 | 1978     | + 8 | 1973     | +11 | 1979     | -31 |

NOTE: "% Δ" are the percent departures from the monthly average of the precipitation and snowfall occurrence frequencies.

#### IV. NEAR-TYPICAL MONTHS FOR BOTH AVIATION WEATHER AND PRECIPITATION FREQUENCY

Months having typical aviation weather do not necessarily have typical precipitation (or snowfall) frequency. In fact, an attempt to match up top-ranked typical months of both categories, as is done in Table 11, produces results that can be expected to be equaled or exceeded by random chance with a probability of 0.66. Of the top three typical aviation weather months over all months of the year (36 months in all), only 12 were matched by top-three precipitation months.

These results led to an examination of the correlation between ceiling/visibility (good day/bad day) and precipitation frequency departures from average. Correlating the percent departures of these two variables over all months for all years, the correlation coefficient,  $r$ , is essentially zero ( $r = +0.012$ ). However, the correlation for summer months (May through August) and winter months (November through February) separately produced quite different results. In summertime,  $r = -0.53$ , which is a moderately strong correlation, implying that summer months having better than average aviation weather have less frequent precipitation than average. In wintertime,  $r = +0.24$ , which is a weak but possibly meaningful correlation that would indicate the opposite relationship, better than average aviation weather is associated with more frequent than average precipitation. The linear regression lines associated with these seasonal correlations are shown in Fig. 7.

These opposing relationships between summer and winter have a plausible explanation. The typical summer atmosphere is slightly unstable and vertically "well mixed" with mild maritime air being heated by the underlying land mass, resulting in good visibilities and few low clouds. Much of the poor aviation weather in summer is associated with transient disturbances, such as fronts and instability lines, which also bring most of the precipitation. The typical winter atmosphere, however, is very stable, quite stagnant with high relative humidity,

Table 11  
 MATCH-UP OF MONTHS HAVING NEAR-TYPICAL AVIATION WEATHER (A)  
 AND PRECIPITATION FREQUENCY (P)

| Month     | 1973  | 1974  | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 |
|-----------|-------|-------|------|------|------|------|------|------|------|------|------|
|           | A P   | A P   | A P  | A P  | A P  | A P  | A P  | A P  | A P  | A P  | A P  |
| January   | 3     |       |      |      | 3    |      | 2    | 1    | 1    |      | 2    |
| February  | 3     | 2     |      |      |      |      | 1 3  | 1    | 2    |      |      |
| March     | 3     |       | 3    | 1    |      |      | 2    | 2    |      |      | 1    |
| April     | 3 2   |       | 3 1  |      | 2    |      |      |      |      |      | 1 3  |
| May       | 3     | 2 2   |      |      |      | 3    |      | 2    | 1    |      | 1    |
| June      | 2     | 1     | 3    |      | 2    | 1    |      | 3    |      |      |      |
| July      | 1     | 1     |      | 3    | 3    | 2 2  | 3    |      |      |      |      |
| August    |       | 2 2 1 |      |      |      |      | 3    | 3    |      |      | 1    |
| September |       | 1     |      |      | 2    | 1    | 2 3  |      | 3 3  |      |      |
| October   | 2 2 1 |       |      |      |      | 3    | 1    | 1    |      | 3    |      |
| November  | 1 2   |       | 3 3  |      |      |      |      | 2    |      |      |      |
| December  | 2 1   |       |      |      |      | 3    |      | 1 2  |      | 2    |      |

NOTE: Numbers are typicality rankings.

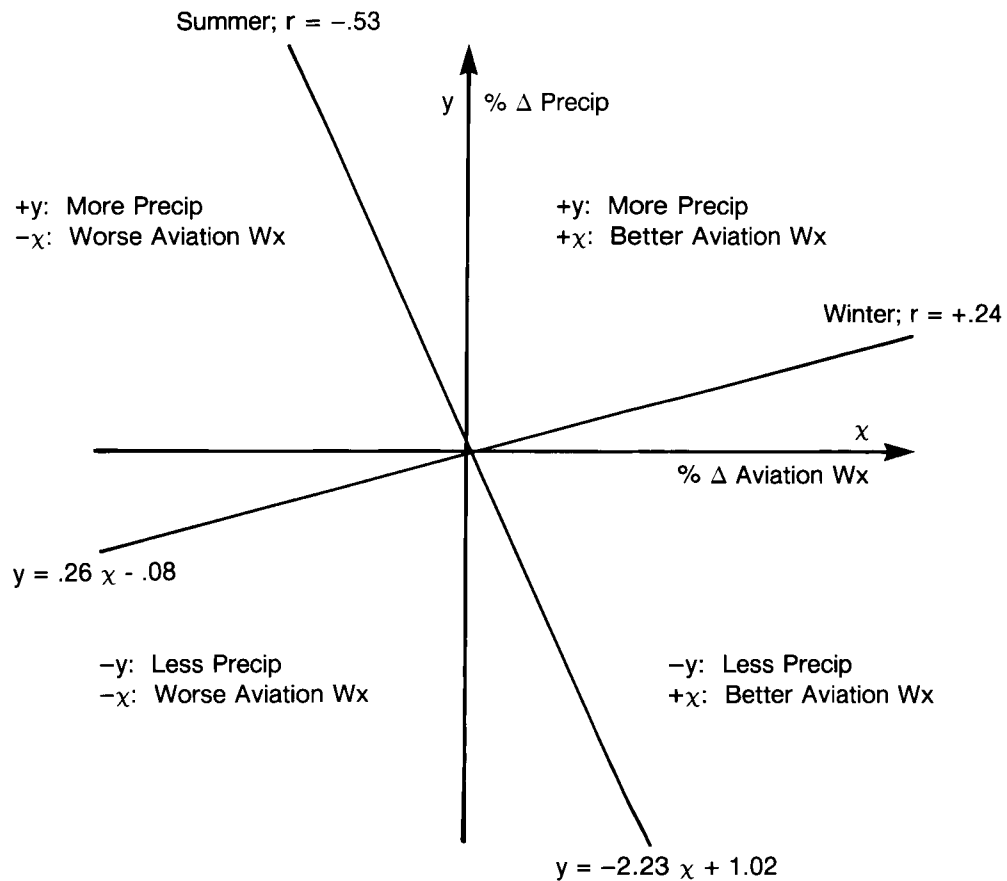


Fig. 7 -- Linear regressions of y (% Δ precipitation) on x (% Δ aviation weather) for summer (May through August) and winter (November through February)

laden with aerosols (pollutants and fog), and often low overcast clouds-- poor aviation weather. The storms and fronts that bring much of the winter precipitation simultaneously relieve the stagnant conditions and thus provide temporary respite from the characteristically low visibilities.

## V. SELECTING "WEATHER MONTHS" FOR STUDY PURPOSES

Normally, an analyst will wish to ensure that the effects of weather on his or her battle simulation study are within reasonable bounds of statistically expected weather effects. One reason for this weather "typicality" analysis is to help avoid the accidental selection of extreme weather periods that could seriously distort study results. Although "typical" may be a somewhat misleading term when applied to highly variable weather conditions, the typical months identified here are at least near the middle between the extremes.

Another facet of the problem that this analysis highlights is the seasonality of German weather. One is forced, by nature itself, to deal with a specific time of year for any battle simulation. Seasonal differences in weather effects on warfare, not to mention the difference in day and night durations, could have enormous effects on battle progress and parameters, real and simulated. If nonweather factors dictate the choice of season for a simulation (such as annual periods of peak Warsaw Pact readiness), then this work enables the researcher to pick the least unusual weather for the dictated months. If one wishes to minimize seasonal effects altogether, then one might choose, with care, one or more near-equinox months (March, April, September, or October) as the weather framework for the study. It might be valuable, however, to produce seasonal bounds on simulation results by running it in both typical summer and typical winter weather.

Speaking of "bounds on results," the large variability of weather, especially in winter months, suggests that "worst case" simulations might at times give important information. As can be seen in Fig. 6, the frequency with which winter-month  $\Delta \leq -5$  (worst one-third of the departures) is about 25 percent. This analysis provides the necessary data to select worst-case (and best-case) months.

The near-independence of aviation weather (ceiling and visibility) and precipitation frequency could lead to some problems in deciding on typical weather periods. Finding months that are near-typical on all



counts is, practically speaking, a matter of chance (as per Table 11). In all past RAND studies for the Air Force, emphasis has been very strongly on aviation weather and its effects, letting precipitation fall where it may. Such may be the case for most future studies, but each simulation project should be judged individually with regard to the potential importance of precipitation effects on, say, land mobility and infrared sensors. If the weather month for a simulation were to be drawn from the three most typical aviation weather months (for any calendar month), the range of precipitation-frequency anomalies that would have to be accepted are as shown in Table 12. As a hypothetical example, if it were important to have near-typical snowfall in a particular January simulation, Table 12 would indicate a real problem. However, referring to the more complete data in Tables 3 and 9, we find that the fourth most typical January for aviation weather, 1982, was *the* most typical January for snowfall frequency--possibly a good compromise choice for that particular simulation criterion.

As a final comment regarding "weather month" selection, it must be said that this analysis stops just short of being complete. One more step will be necessary. The day-to-day sequences of weather conditions will have to be examined within the selected months. An earlier RAND study<sup>1</sup> demonstrated that the temporal distribution of weather can have considerable effects on "short wars." The main pitfall to be avoided is the commencement of a short-war simulation in a protracted period of either very good or very bad weather, which can occur even in typical months. Judgment in this matter will depend on several factors, including the season of the year, the driving weather effects, and even whether the aggressor might use weather forecasts as input to the timing of the initial attack.

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<sup>1</sup>R. E. Huschke, *Tactical Airpower in NATO Contingencies--Modeling Weather Constraints on Air Operations: Weather and Warplanes IV*, The RAND Corporation, R-1195-1-PR, January 1974.

Table 12

PRECIPITATION AND SNOWFALL FREQUENCY ANOMALIES IN MONTHS OF  
NEAR-TYPICAL AVIATION WEATHER

| Month     | 1st Rank |             |      | 2nd Rank |             |      | 3rd Rank |             |      |
|-----------|----------|-------------|------|----------|-------------|------|----------|-------------|------|
|           | Year     | % Departure |      | Year     | % Departure |      | Year     | % Departure |      |
|           |          | Precip      | Snow |          | Precip      | Snow |          | Precip      | Snow |
| January   | 1981     | + 26        | + 83 | 1979     | + 21        | +127 | 1974     | - 20        | - 83 |
| February  | 1979     | + 14        | + 46 | 1981     | + 25        | + 59 | 1973     | + 35        | + 16 |
| March     | 1977     | - 22        |      | 1979     | + 45        |      | 1973     | - 35        |      |
| April     | 1983     | + 29        |      | 1977     | + 41        |      | 1975     | + 2         |      |
| May       | 1983     | + 42        |      | 1980     | - 51        |      | 1975     | - 32        |      |
| June      | 1974     | + 13        |      | 1973     | - 23        |      | 1980     | + 19        |      |
| July      | 1974     | + 43        |      | 1978     | + 7         |      | 1976     | - 34        |      |
| August    | 1983     | - 18        |      | 1975     | - 3         |      | 1979     | + 18        |      |
| September | 1978     | +102        |      | 1979     | - 4         |      | 1982     | - 68        |      |
| October   | 1974     | +106        |      | 1973     | - 7         |      | 1982     | + 15        |      |
| November  | 1974     | + 4         | - 51 | 1980     | + 15        | +126 | 1976     | + 9         | - 26 |
| December  | 1980     | + 7         | + 36 | 1982     | - 21        | - 64 | 1973     | - 1         | + 11 |

