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ADVERSE WEATHER TEST SITE SELECTION STUDY

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This report details the percent frequency of occurrence of the adverse weather testing criteria (as outlined in AFFTC-TIH-88-004) for five airfields: Keflavik, Iceland; Goose Bay, Canada; Bodo, Norway; Volk Field, WI; and Dover AFB, DE. The data assists selection of a single location best suited, climatologically, to perform flight testing. Criteria tested and weather conditions evaluated include artificial and natural in-flight icing and rain; wet, slushy, and icy runway/taxiway performance and handling qualities; freezing rain exposure; engine water ingestion on the ground and in-flight; evaluation of instrument flight rules (IFR) capability; evaluation of the effects of corrosive atmospheric pollutants; and turbulent flight evaluation. Numerous tables and graphs are used to demonstrate the percent frequency differences of the adverse weather conditions between the five locations.

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Summary

The problem posed in selecting a single adverse weather site based solely on climatology is a formidable one. Adverse weather testing requires such a comprehensive range of conditions that no single site can satisfy every criteria, and climatology cannot guarantee a condition's occurrence. Given five locations -- Keflavik, Iceland; Bodo, Norway; Goose Bay, Canada; Volk Field, Wisconsin; and Dover AFB, Delaware -- we set out to determine which site had the best chance of satisfying the test criteria as defined by the Air Force Flight Test Center (AFFTC) report Flight Testing Under Extreme Climatic Conditions (AFFTC-TIH-88-004).

We defined weather conditions which would satisfy the testing requirements, then separated them into observable weather elements (e.g., frozen precipitation, a range in temperature, etc). We conducted a statistical study involving those elements, the results of which formed the basis of a ranking scheme devised to differentiate between locations. Because some of the percentages for certain elements were too close to call, any element for which all locations showed a less than 10 percent difference was eliminated from final computation. The top 3 recommended locations per season (in rank order) are listed below:

Spring

1. Keflavik, Iceland
2. Goose Bay, Canada
3. Bodo, Norway

Fall

1. Keflavik, Iceland
2. Bodo, Norway and Goose Bay, Canada

Summer

1. Keflavik, Iceland
2. Goose Bay, Canada
3. Bodo, Norway

Winter

1. Bodo, Norway
2. Keflavik, Iceland
3. Goose Bay, Canada

As a reiteration, climatology does not guarantee the occurrence of certain conditions. Therefore, dependence on any single site would be unwise. Also, since some of the undependable elements are reproducible in the climatic hanger, removal of them from these computations (and the site test docket) may provide an even clearer picture.

1. Introduction

Selection of a site for adverse weather testing can be extremely costly and time consuming. Improper site selection leads to wasted time and money during both site surveys and the adverse weather testing. To assist the C-17 Combined Test Force (CTF) and the C-17 Systems Program Office (SPO), we, in conjunction with the USAF Environmental Technical Applications Center (USAFETAC), performed a climatological study of five locations in the continental United States (CONUS) and overseas. The purpose of the study was to use climatology to determine the most favorable location for C-17 Adverse Weather Testing.

2. Methods, Assumptions and Procedures

A. Adverse Weather Testing Criteria and Weather Conditions

The criteria for adverse weather testing are published in Flight Testing Under Extreme Climatic Conditions (AFFTC-TIH-88-004) and are listed below:

1. Artificial and natural in-flight icing and rain.
2. Wet, slushy, and icy runway/taxiway performance and handling qualities.
3. Freezing rain exposure.
4. Engine water ingestion on the ground and in-flight.
5. Evaluation of Instrument Flight Rules (IFR) capability.
6. Evaluation of the effects of corrosive atmospheric pollutants.
7. Turbulent flight evaluation.

The AFFTC document also describes the weather conditions conducive to the desired test criteria listed above. They are as follows:

1. Ambient temperature in the range of 20°F to 40°F (-7°C to 4°C)
2. Frequent exposure to rain, snow, and freezing rain.
3. Slippery taxiways and runways with a runway condition rating as low as six.
4. Crosswind components up to 20 kts during taxi, takeoff, and landing.
5. High surface winds over salt water.
6. Instrument Meteorological Conditions (IMC) for in-flight evaluation.
7. Temperature/humidity combinations conducive to airframe/engine icing during ground operations.
8. The "natural in-flight icing" does not have a corresponding weather condition. For this study, we added the weather condition "exposure to natural icing" to the weather condition list.

B. Locations

The locations evaluated, along with a brief description of the meteorological data used to produce the climatology, are listed below:

1. Volk Field, Wisconsin (KVOK)

a. The surface data is limited to daylight hours except when Air National Guard units are using the airfield. The period of record for the surface data used to generate the climatology is January 1973 to December 1989. Because of limited data we used La Crosse, Wisconsin (KLSE) as a secondary data point. La Crosse is located 78 km west of Volk Field. The period of record for the La Crosse surface data is from January 1973 to December 1989. The crosswind information at La Crosse should not be considered representative of Volk Field since different runway headings and local wind effects are present. Therefore, we did not include La Crosse crosswind information.

b. The upper air data is from Green Bay, Wisconsin located 237 km northeast of Volk Field. The period of record for the upper air data used to generate the climatology is January 1973 to December 1988.

2. Keflavik, Iceland (BIKF)

   a. The surface data is from Keflavik. The period of record is January 1973 to December 1989.

   b. The upper air data is from Keflavik. The period of record is January 1973 to December 1988.

3. Bodo, Norway (ENBO)

   a. The surface data is from Bodo. The period of record is January 1973 to December 1989.

   b. The upper air data is from Bodo. The period of record is January 1973 to December 1988.

4. Goose Bay, Canada (CYYR)

   a. The surface data is from Goose Bay. The period of record is January 1973 to December 1987.

   b. The upper air data is from Goose Bay. The period of record is January 1973 to December 1988.

5. Dover AFB, Delaware (KDOV)

   a. The surface data is from Dover AFB. The period of record is January 1973 to December 1989.

   b. The upper air data is from Atlantic City, New Jersey, located 83 km from Dover AFB. The period of record is October 1980 to December 1990.

C. Climatological Statistics

The climatological occurrence of weather conditions can be expressed in many forms. For this study we used the following:

1. Percentage Frequency. The amount of time (expressed as a percentage) per month the condition was measured or observed to occur during the period of record.

2. Average Number of Durations Annually. The average number of times per year the condition occurred during the period of record.

3. Average Length (Hours) of Durations. The average length in hours the condition occurred during the period of record. Average length of durations is *independent* of the average number of durations and represents the length of the occurrence *when* the element occurs.

4. Wind Roses. Percent frequency for both wind direction and wind speed.

5. Probability of Icing. There is no icing climatology by location. Consequently, we used an empirical method derived by the USAF Air Weather Service to determine the amount of time aircraft icing could have occurred. More information on this technique may be found in AWS/TR-80/001, Forecaster's Guide on Aircraft Icing. Based upon our experience, the percentage frequency computed in this manner may overestimate the amount of time icing occurred.

D. Weather Elements

We evaluated the climatological occurrence of weather elements producing the weather conditions needed for adverse weather testing. The evaluated weather elements are as follows:

1. Temperature Greater Than or Equal to (GTE) 20°F and Less Than or Equal to (LTE) 40°F.

2. Non-Freezing Precipitation. *Non-freezing* is defined as precipitation not observed to freeze upon contact with surfaces. The occurrence of either rain, rain or drizzle and snow, snow, snow showers, mixed rain and snow showers, rain showers, hail, and thunderstorms. The occurrence of any of these types of precipitation counts within this category.

3. Snow or Ice Pellets Not Including Freezing Precipitation. The occurrence of either snow or ice pellets.

4. Freezing Precipitation. The occurrence of freezing rain or drizzle.

5. Crosswinds. We used true compass headings for the crosswinds statistics generation. Runway headings listed after the station on the crosswind charts are true compass headings. Goose Bay, Dover AFB, and Keflavik all have multiple runways. Supplemental charts are included for these locations' additional runways. Crosswind statistics are based upon two ranges: crosswinds between 1 and 10 kts and crosswinds between 11 and 20 kts. Runways are defined as Primary and Secondary. Our definition of primary and secondary is based on the annual percentage frequency of occurrence. The runway with the highest frequency of occurrence is the primary runway; all others are secondary runways.

6. Temperature LTE 40°F, Relative Humidity GTE 80 percent, and Precipitation. The simultaneous occurrence of temperature less than or equal to 40°F, relative humidity greater than or equal to 80 percent, and precipitation. Precipitation types include fog, patchy fog, ice fog, drizzle, freezing drizzle, drizzle and rain, rain, freezing rain, rain or drizzle and snow, snow, snow grains, ice pellets, rain showers, mixed rain and snow showers, hail, and thunderstorms.

All three conditions (temperature, relative humidity, and precipitation) must have occurred simultaneously to be counted in this category.

7. Winds. We used wind roses to determine the approximate amount of time the wind flow came from the ocean. This approach assumes sea salts are present in the wind. If the air terminal is located more than 20 miles from the ocean, we assumed the location had 0 percent occurrence of sea salts in the air.

8. Precipitation Not Freezing and Temperature GTE 20°F, but LTE 40°F. The simultaneous occurrence of temperatures between 20°F and 40°F and precipitation. Precipitation types include rain, rain or drizzle and snow, rain showers, mixed rain and snow showers, hail, and thunderstorms.

9. Fog or Mist and Temperature GTE 20°F, but LTE 40°F. The simultaneous occurrence of temperature between 20°F and 40°F and either fog or mist. Fog types include patchy ice fog or fog.

10. Drizzle and Temperature GTE 20°F, but LTE 40°F. The simultaneous occurrence of temperature between 20°F and 40°F and drizzle. Occurrences of drizzle and rain were also counted in the precipitation category.

11. Ceilings Less Than (LT) 3000 feet or Visibility LT 3 miles.

12. Ceilings LT 1000 feet or Visibility LT 2 miles.

13. Ceilings LT 200 feet or Visibility LT 1/2 mile.

14. Probability of Icing. The probability of icing is evaluated at four altitudes (5,000, 10,000, 18,000, and 23,000 feet). However, the probabilities were computed for pressure altitudes. Therefore, deviations from the approximate altitudes referenced above are possible.

E. Site selection

First we grouped each of the weather *elements* under the appropriate weather *conditions*:

1. Ambient temperature in the range of 20°F to 40°F (-7°C to 4°C). Temperature GTE 20°F and LTE 40°F.

2. Frequent exposure to rain, sleet, snow, and freezing rain.

   a. Non-Freezing Precipitation.

   b. Snow or Ice Pellets.

   c. Freezing Precipitation.

3. Slippery taxiways and runways with a runway condition rating as low as six. Currently a methodology does not exist to infer exact runway conditions from climatology. For this study, it is assumed the following weather elements will always produce a lower runway condition rating than normal. Climatological conditions in this study do not guarantee a runway condition of six.

a. Non-Freezing Precipitation.

b. Snow or Ice Pellets.

c. Freezing Precipitation.

4. Crosswind components up to 20 kts during taxi, takeoff, and landing.

a. Crosswinds between 1 and 10 kts.

b. Crosswinds between 11 and 20 kts.

5. High surface winds over salt water. The amount of time the wind flow came from the ocean is used as a subjective indicator of sea salts over the station. Volk Field and Goose Bay are sufficiently inland to remove the likelihood of evaporated sea salts in the wind.

6. Instrument meteorological conditions for in-flight evaluation.

a. Ceilings LT 3000 feet or Visibility LT 3 miles.

b. Ceilings LT 1000 feet or Visibility LT 2 miles.

c. Ceilings LT 200 feet or Visibility LT 1/2 mile.

7. Temperature/humidity combinations conducive to airframe/engine icing during ground operations.

a. Temperature LTE 40°F, Relative Humidity GTE 80 percent, and Precipitation.

b. Precipitation Not Freezing and Temperature GTE 20°F, but LTE 40°F.

c. Fog or Mist and Temperature GTE 20°F, but LTE 40°F.

d. Drizzle and Temperature GTE 20°F, but LTE 40°F.

8. Exposure to natural in-flight icing. Probability of icing.

We ranked, by season, each location and weather element using the following process:

1. The seasonal breakdown is Spring (March, April, May), Summer (June, July, August), Fall (September, October, November) and Winter (December, January, February).

2. Excluding "high winds over salt water," seasonal rankings were determined by percent frequency. Ranking values ranged from 1 (highest percentage frequency for the season) to 5

(lowest percentage frequency for the season). If any location had 0 percent frequency for all months in a season, the location is ranked fifth.

3. We used the total of all weather element rankings for each weather condition to determine the best location by season for each condition. Lower totals are indicative of higher percentage frequency values. For example, consider the weather condition "frequent exposure to rain, sleet, snow, and freezing rain." If the percent frequency of "non-freezing precipitation" was highest at Keflavik, Iceland during Spring, and Bodo, Norway was second, Keflavik would receive a 1 for "non-freezing precipitation" and Bodo a 2 for "non-freezing precipitation." Now if Keflavik was ranked second for "snow or ice pellets and freezing precipitation" and Bodo was ranked fourth, Keflavik would have a total of 5 and Bodo a total of 10. Keflavik would be rated as the best location for "frequent exposure to rain, sleet, snow, and freezing rain" for Spring.

4. When 2 locations had the same total for a weather condition, the rankings for the **least** percent frequency weather element were used to resolve the tie.

5. For the weather condition "high winds over salt waters," Goose Bay and Volk Field are ranked fifth because of their respective distances from the ocean. Dover AFB, though closer to the coast, is still sufficiently inland to reduce the amount of sea salts which could reach the station. Therefore, Dover AFB is automatically ranked third regardless of the amount of time the wind came from the ocean.

6. We ranked crosswind based on the primary runway at each location.

Based upon a location's final standing by season for each weather condition, another rank is assigned. The ranking assigned ranges from 1 (best) to 5 (worst). These rankings are totalled to determine the best location by season for all weather conditions. Continuing the example from above, Keflavik would receive a 1 and Bodo a 2 during Spring for "frequent exposure to rain, sleet, snow, and freezing rain." Now if Keflavik received 5s for all other weather conditions and Bodo received 1s, Bodo would have the lowest total and highest ranking.

The above mentioned ranking scheme fails to account for elements where there is little or no difference in percent frequency, making discrimination between locations difficult. Therefore, we re-examined all of the elements comprising the weather conditions and removed all elements where the difference between all locations is 10 percent or less. The process is the same as outlined above, but elements not meeting the criteria were removed from the rankings for each weather condition. If all the elements comprising the condition were removed, the condition was removed from the final computations. The rankings derived in this manner are the basis for our recommendations for adverse weather testing site selection.

F. Limitations of This Study

The methodology described above addresses only the highest percent frequency. It does not track the actual amount of time the conditions occur. Therefore, it is possible to select a location where the amount of time the condition occurs is insufficient for testing purposes. In order to identify those locations and times of the year where the actual amount of time may be lower than

testing requirements, we identified (see section 3) the locations where weather elements comprising the weather condition were below 10 percent frequency. Ten percent frequency is approximately 72 hours for a 30-day month. We included the average number of durations annually and the average length of durations for all elements (Appendix B), except the "probability of icing" and "surface wind over salt water."

Climatological expressions of weather conditions are averaged values and may over or under represent the weather conditions experienced in any given year. Therefore, it is best to select multiple locations and develop contingency plans in advance for last-minute site changes.

3. Results and Discussion

To initially rank, by season, each site for adverse weather testing, we gave equal weight to each weather condition mentioned in the previous section of this report. We used the sum total of each condition (A through H in Table 1) to determine the relative order (rank) of each location. Keflavik scored the best in every season except the Fall (see Appendix A for individual weather element ranking and computations).

Table 1: Location ranking using all weather condition

Spring	A	B	C	D	E	F	G	H	Total	Rank
Keflavik	3	4	4	3	1	2	1	2	20	1
Goose Bay	4	1	1	2	5	4	2	1	20	1
Volk Field	1	2	2	4	5	3	3	3	23	2
Bodo	2	5	5	1	2	5	4	4	28	3
Dover AFB	5	3	3	5	3	1	5	5	30	4

Summer	A	B	C	D	E	F	G	H	Total	Rank
Keflavik	3	1	1	1	2	1	1	3	13	1
Goose Bay	1	2	2	2	5	5	2	1	20	2
Bodo	4	3	3	3	1	3	3	2	22	3
Dover AFB	5	4	4	5	3	2	5	4	32	4
Volk Field	2	5	5	4	5	4	4	5	34	5

Fall	A	B	C	D	E	F	G	H	Total	Rank
Goose Bay	2	1	1	1	5	4	1	1	16	1
Keflavik	3	3	3	2	2	1	2	2	18	2
Bodo	4	2	2	4	1	5	4	3	25	3
Volk Field	1	4	4	3	5	2	3	4	26	4
Dover AFB	5	5	5	5	3	3	5	5	36	5

Winter	A	B	C	D	E	F	G	H	Total	Rank
Keflavik	1	5	5	3	1	2	1	2	20	1
Bodo	2	4	4	1	2	4	3	3	23	2
Volk Field	4	1	1	5	5	3	2	4	25	3
Dover AFB	3	2	2	4	3	1	5	5	25	3
Goose Bay	5	3	3	2	5	5	4	1	28	4

A - ambient temperature in the range of 20°F to 40°F, **B** - Frequent exposure to rain, snow, and freezing rain, **C**- Slippery taxiways and runways with a runway condition rating as low as six, **D** - Crosswind components up to 20 kts during taxi, takeoff, and landing, **E** - High surface winds over salt water, **F** - Instrument meteorological conditions for in-flight evaluation, **G** - Temperature/humidity combinations conducive to airframe engine icing during ground operations, and **H** - exposure to natural in-flight icing.

To account for the climatological variance between conditions at each location we eliminated the elements with less than 10 percent difference in frequency of occurrence at all locations. After eliminating the elements we reranked each location by season (Table 2a through 2d). The elements we removed are listed below each table. The elements are defined the same as Table 1. An asterisk denotes an eliminated weather condition.

Table 2a: Spring location ranking after eliminating the elements with less than 10 percent difference between all locations

Spring	A	B	C	D	E	F	G	H	Total	Rank
Keflavik	3	3	3	3	1	2	2	2	19	1
Goose Bay	4	1	1	2	5	4	3	1	21	2
Bodo	2	4	4	1	2	5	1	3	22	3
Volk Field	1	2	2	4	5	1	4	4	23	4
Dover AFB	5	5	5	5	3	3	5	5	36	5

Non-freezing precipitation
Freezing precipitation
Ceiling LT 200 feet or visibility LT 1/2 mile
Fog or mist and temperature GTE 20°F, but LTE 40°F
Drizzle and temperature GTE 20°F, but LTE 40°F

Table 2b: Summer location ranking after eliminating the elements with less than 10 percent difference between all locations

Summer	A	B	C	D	E	F	G	H	Total	Rank
Keflavik	*	3	3	1	2	1	*	*	10	1
Goose Bay	*	1	1	2	5	2	*	*	11	2
Bodo	*	2	2	3	1	5	*	*	13	3
Dover AFB	*	4	4	5	3	3	*	*	19	4
Volk Field	*	5	5	4	5	4	*	*	23	5

Temperature GTE 20°F and LTE to 40°F
Snow or ice pellets
Freezing precipitation
Ceiling LT 200 feet or visibility LT 1/2 mile
Temperature LTE 40°F, RH GTE 80%, and precipitation
Precipitation not freezing and temperature GTE 20°F, but LTE 40°F
Fog or mist and temperature GTE 20°F, but LTE 40°F
Drizzle and temperature GTE 20°F, but LTE 40°F
Probability of icing

Table 2c: Fall location ranking after eliminating the elements with less than 10 percent difference between all locations

Fall	A	B	C	D	E	F	G	H	Total	Rank
Keflavik	3	3	3	2	2	2	2	2	19	1
Bodo	4	1	1	4	1	5	1	3	20	2
Goose Bay	2	2	2	1	5	4	3	1	20	2
Volk Field	1	5	5	3	5	1	4	4	28	3
Dover AFB	5	4	4	5	3	3	5	5	34	4

Snow or ice pellets
Freezing precipitation
Ceiling LT 200 feet or visibility LT 1/2 mile
Fog or mist and temperature GTE 20°F, but LTE 40°F
Drizzle and temperature GTE 20°F, but LTE 40°F

Table 2d: Winter location ranking after eliminating the elements with less than ten percent difference between all locations

Winter	A	B	C	D	E	F	G	H	Total	Rank
Bodo	2	2	2	1	*	4	4	3	18	1
Keflavik	1	5	5	3	*	2	1	2	19	2
Goose Bay	5	1	1	2	*	5	5	1	20	3
Volk Field	4	4	4	5	*	1	2	4	24	4
Dover AFB	3	3	3	4	*	3	3	5	24	4

Freezing precipitation
Ceiling LT 200 feet or visibility LT 1/2 mile
Temperature LTE 40°F, RH GTE 80%, and precipitation
Drizzle and temperature GTE 20°F, but LTE 40°F

After elimination of the weather elements with little difference between locations (less than 10 percent), the tie between Keflavik and Goose Bay is resolved (Table 2). The summer ranking did not change. The large number of elements eliminated is indicative of little climatological difference between the stations during the summer. In general, the low frequency of occurrence of adverse weather during the summer reduces the chances of completing the Adverse Weather Tests. In the fall, when precipitation elements were removed, Keflavik is ranked first (Table 2c). Keflavik dropped in ranking during the winter, when some adverse weather elements were removed. However, the elements eliminated should be easily replicated in the McKinley Climatic Laboratory.

We discovered every potential test site had at least one rare (less than 10 percent frequency of occurrence) weather condition (Table 3a through 3d). Therefore, it may be difficult to complete every adverse weather test condition at one location during one season.

Table 3a: Spring weather elements with less than 10 percent frequency of occurrence

Location	Weather Elements < 10%
Keflavik	- Snow or ice pellets - Freezing precipitation - Ceilings LT 200 feet and visibility LT 1/2 mile - Fog or mist and temperature GTE 20°F, but LTE 40°F - Drizzle and temperature GTE 20°F, but LTE 40°F - Temperature LTE 40°F, RH GTE 80% and precipitation
Goose Bay	- Freezing precipitation - High surface winds over salt water - Ceilings LT 200 feet and visibility LT 1/2 mile - Fog or mist and temperature GTE 20°F, but LTE 40°F - Drizzle and temperature GTE 20°F, but LTE 40°F - Ceilings LT 1000 feet or visibility LT 2 miles - Precipitation not freezing and temperature GTE 20°F, but LTE 40°F
Bodo	- Snow or ice pellets - Freezing precipitation - Ceilings LT 1000 feet or visibility LT 2 miles - Ceilings LT 200 feet and visibility LT 1/2 mile - Fog or mist and temperature GTE 20°F, but LTE 40°F - Drizzle and temperature GTE 20°F, but LTE 40°F - Temperature LTE 40°F, RH GTE 80%, and precipitation
Volk Field	- Snow or ice pellets - Freezing precipitation - High surface winds over salt water - Ceilings LT 200 feet and visibility LT 1/2 mile - Fog or mist and temperature GTE 20°F, but LTE 40°F - Drizzle and temperature GTE 20°F, but LTE 40°F - Temperature LTE 40°F, RH GTE 80%, and precipitation - Non-freezing precipitation - Precipitation not freezing and temperature GTE 20°F, but LTE 40°F
Dover AFB	- Snow or ice pellets - Freezing precipitation - Ceilings LT 200 feet and visibility LT 1/2 mile - Fog or mist and temperature GTE 20°F, but LTE 40°F - Drizzle and temperature GTE 20°F, but LTE 40°F - Precipitation not freezing and temperature GTE 20°F, but LTE 40°F - Temperature LTE 40°F, RH GTE 80%, and precipitation - Exposure to natural in-flight icing

Table 3b: Summer weather elements with less than ten percent frequency of occurrence

Location	Weather Elements < 10%
Keflavik	- Temperature GTE 20°F and LTE 40°F - Snow or ice pellets - Freezing precipitation - Ceilings LT 200 feet and visibility LT 1/2 mile - Temperature LTE 40°F, RH GTE 80%, and precipitation - Fog or mist and temperature GTE 20°F but LTE 40°F - Precipitation not freezing and temperature GTE 20°F, but LTE 40°F - Drizzle and temperature GTE 20°F, but LTE 40°F
Goose Bay	- Temperature GTE 20°F and LTE 40°F - Snow or ice pellets - Freezing precipitation - High surface winds over salt water - Ceilings LT 200 feet and visibility LT 1/2 mile - Temperature LTE 40°F, RH GTE 80%, and precipitation - Fog or mist and temperature GTE 20°F, but LTE 40°F - Drizzle and temperature GTE 20°F, but LTE 40°F - Ceilings LT 1000 feet or visibility LT 2 miles - Precipitation not freezing and temperature GTE 20°F, but LTE 40°F
Bodo	- Temperature GTE 20°F and LTE 40°F - Snow or ice pellets - Freezing precipitation - Ceilings LT 200 feet and visibility LT 1/2 mile - Temperature LTE 40°F, RH GTE 80%, and precipitation - Fog or mist and temperature GTE 20°F, but LTE 40°F - Drizzle and temperature GTE 20°F, but LTE 40°F - Crosswinds between 11 and 20 kts - Ceilings LT 1000 feet or visibility LT 2 miles - Precipitation not freezing and temperature GTE 20°F, but LTE 40°F
Dover AFB	- Temperature GTE 20°F and LTE 40°F - Snow or ice pellets - Freezing precipitation - Crosswinds between 11 and 20 kts - Ceilings LT 200 feet and visibility LT 1/2 mile - Temperature LTE 40°F, RH GTE 80%, and precipitation - Precipitation not freezing and temperature GTE 20°F, but LTE 40°F - Fog or mist and temperature GTE 20°F, but LTE 40°F - Drizzle and temperature GTE 20°F, but LTE 40°F - Non-freezing precipitation - Ceilings LT 1000 feet or visibility LT 2 miles - Exposure to natural in-flight icing
Volk Field	- Non-freezing precipitation - Crosswinds between 11 and 20 kts - Ceilings LT 1000 feet or visibility LT 2 miles - Exposure to natural in-flight icing

Table 3c: Fall weather elements with less than ten percent frequency of occurrence

Location	Weather Elements < 10%
Keflavik	- Snow or ice pellets - Freezing precipitation - Ceilings LT 200 feet and visibility LT 1/2 mile - Fog or mist and temperature GTE 20°F, but LTE 40°F - Drizzle and temperature GTE 20°F, but LTE 40°F - Temperature LTE 40°F, RH GTE 80%, and precipitation
Bodo	- Snow or ice pellets - Freezing precipitation - Crosswinds between 11 and 20 kts - Ceilings LT 1000 feet or visibility LT 2 miles - Ceilings LT 200 feet and visibility LT 1/2 mile - Fog or mist and temperature GTE 20°F, but LTE 40°F - Drizzle and temperature GTE 20°F, but LTE 40°F - Temperature LTE 40°F, RH GTE 80%, and precipitation
Goose Bay	- Freezing precipitation - High surface winds over salt water - Ceilings LT 200 feet and visibility LT 1/2 mile - Fog or mist and temperature GTE 20°F but LTE 40°F - Drizzle and temperature GTE 20°F, but LTE 40°F - Ceilings LT 1000 feet or visibility LT 2 miles - Snow or ice pellets
Volk Field	- Snow or ice pellets - Freezing precipitation - High surface winds over salt water - Ceilings LT 200 feet and visibility LT 1/2 mile - Temperature LTE 40°F, RH GTE 80%, and precipitation - Precipitation not freezing and temperature GTE 20°F, but LTE 40°F - Fog or mist and temperature GTE 20°F, but LTE 40°F - Drizzle and temperature GTE 20°F, but LTE 40°F - Non-freezing Precipitation - Crosswinds between 11 and 20 kts
Dover AFB	- Snow or ice pellets - Freezing precipitation - Ceilings LT 200 feet and visibility LT 1/2 mile - Temperature LTE 40°F, RH GTE 80%, and precipitation - Precipitation not freezing and temperature GTE 20°F, but LTE 40°F - Fog or mist and temperature GTE 20°F, but LTE 40°F - Drizzle and temperature GTE 20°F, but LTE 40°F - Temperature GTE 20°F and LTE 40°F - Crosswinds between 11 and 20 kts - Exposure to natural in-flight icing

Table 3d: Winter weather elements with less than ten percent frequency of occurrence

Location	Weather Elements < 10%
Bodo	- Freezing precipitation - Ceilings LT 200 feet or visibility LT 1/2 mile - Fog or mist and temperature GTE 20°F but LTE 40°F - Drizzle and temperature GTE 20°F, but LTE 40°F - Snow or ice pellets - Ceilings LT 1000 feet or visibility LT 2 miles
Keflavik	- Snow or ice pellets - Freezing precipitation - Ceilings LT 200 feet or visibility LT 1/2 mile - Fog or mist and temperature GTE 20°F but LTE 40°F - Drizzle and temperature GTE 20°F, but LTE 40°F
Goose Bay	- Freezing precipitation - High surface winds over salt water - Ceilings LT 200 feet or visibility LT 1/2 mile - Precipitation not freezing and temperatures GTE 20°F but LTE 40°F - Fog or mist and temperature GTE 20°F but LTE 40°F - Drizzle and temperature GTE 20°F, but LTE 40°F - Non-freezing precipitation
Dover AFB	- Freezing precipitation - Ceilings LT 200 feet or visibility LT 1/2 mile - Precipitation not freezing and temperatures GTE 20°F but LTE 40°F - Drizzle and temperature GTE 20°F, but LTE 40°F - Snow or ice pellets - Crosswinds between 11 and 20 kts - Temperature LTE 40°F, RH GTE 80%, and precipitation - Fog or mist and temperature GTE 20°F but LTE 40°F
Volk Field	- Freezing precipitation - Non-freezing precipitation - High surface winds over salt water - Ceilings LT 200 feet or visibility LT 1/2 mile - Precipitation not freezing and temperatures GTE 20°F but LTE 40°F - Drizzle and temperature GTE 20°F, but LTE 40°F

During the Spring, the principle advantage of Keflavik over Goose Bay is the much higher likelihood of sea salts for corrosion. On the other hand, the percent frequency of snow and ice pellets was higher (approximately 13 percent) at Goose Bay. This higher occurrence suggests a higher amount of time for slippery runway evaluation. The difference between Goose Bay and Keflavik for ceilings less than 1000 feet or visibility less than 2 miles is small (approximately 3 percent). Bodo has low percent frequency elements in both precipitation and ceiling/visibility categories.

During the Summer, every location had a low frequency of occurrence for almost every weather element. It would be futile to expect to complete the majority of adverse weather tests at these locations.

In the Fall, snow, ice pellets, and freezing precipitation rarely occur at any of the locations. The primary advantage of Bodo and Keflavik over Goose Bay is the greater likelihood of sea salts for corrosion evaluation. Keflavik has a higher percent frequency of lower ceilings/visibilities and crosswinds than Bodo.

In the Winter, freezing precipitation and extremely low ceiling and visibility are rare at all locations. Fog or mist with temperatures between 20°F and 40°F are also rare at every location accept Volk Field. Even though Bodo has more rare elements, it ranked slightly higher than Keflavik.

Examination of the data reveals all locations have at least one weather condition which may not be encountered during testing. It must be remembered the locations are ranked relative to each other, so the number one location for a given weather condition may not be the number one location to satisfy the original criteria. For the most optimum test results, we suggest careful examination of those tests scheduled for the climatic hanger and those planned for completion on-site. To illustrate why, consider the following example: The percent frequency of freezing precipitation is very low for all locations and seasons. Therefore, all possible test objectives required for exposure to freezing precipitation should be considered for evaluation at the climatic hanger. Since all weather conditions had equal weighting, removing a test objective from consideration at the adverse testing location and meeting that objective at the climatic hanger could change the results presented here. The following discussion will examine by season, those weather elements displaying a low percent frequency.

Even though the locations were ranked, the high number of elements showing low percent frequencies demonstrates a high likelihood of not fulfilling test objectives. We do not recommend testing during summer.

4. Conclusion.

The study provided a good "first step" for any adverse weather test program and will help focus testing efforts at any of the five locations. During every season, except winter, Keflavik ranked the best for Adverse Weather Testing.

Our equal weighting of all weather conditions warrants caution when making a final selection. The System Program Office selection of those weather conditions critical for their adverse weather testing allows "fine tuning" of the results. For example, the C-17 testing group selected certain criteria and narrowed the time scale down to the months they expected to conduct the test to optimize their efforts.

5. Recommendations.

Once the focus of the test is identified, choose those weather conditions which contribute toward fulfilling the test criteria. Be sure to concentrate on those conditions which must occur naturally to be of use to the test (IFR conditions, crosswinds, etc.), since many of the temperature, precipitation, and ground icing criteria can be effectively replicated in the McKinley Climatic Laboratory. The timing of the test may be difficult to forecast; use the information in this report to help narrow the time of year for optimal testing. In addition, should a deadline or tight schedule exist, develop contingency plans to shift locations when possible to avoid wasting time and money waiting at the primary site for a weather event which **is not guaranteed to occur**. The methodology presented in this study provides a simple comparison of frequency of occurrence values. After publishing this report we normalized the values to obtain a more graphic comparison and illustrated the difference between locations (as a percentage), not just a numerical rank order.

References

1. Unpublished Climatic Data, 1991: USAF Environmental Technical Applications Center (USAFETAC), Scott AFB IL.

2. AFFTC-TIH-88-004, 1988: Flight Testing Under Extreme Climatic Conditions.

APPENDIX A

Percent Frequency of Adverse Weather Conditions

Percent Frequency (Figures. A-1 through A-19). All figures present the percent frequency by month the weather element occurred. The bars correspond to locations starting at the top row of the legend and reading from left to right. For example, in Fig. A1 the first column for January indicates a yearly average of 51 percent for Volk Field, 42 percent for La Crosse, 79 percent for Keflavik, 73 percent for Bodo, 11 percent for Goose Bay, and 70 percent for Dover AFB. The same pattern follows for all other charts. Figures are titled as follows:

1. Figure A-1. - Temperature Greater Than or Equal to 20°F and Less Than or Equal to 40°F
2. Figure A-2. - Non-Freezing Precipitation
3. Figure A-3. - Snow or Ice Pellets Not Including Freezing Precipitation
4. Figure A-4. - Freezing Precipitation Rain or Drizzle
5. Figure A-5. - Crosswinds Between 1 and 10 Knots Primary Runways
6. Figure A-6. - Crosswinds Between 1 and 10 Knots Secondary Runways
7. Figure A-7. - Crosswinds Between 11 and 20 Knots Primary Runways
8. Figure A-8. - Crosswinds Between 11 and 20 Knots Secondary Runways
9. Figure A-9. - Ceilings Less Than 3000 feet or Visibility Less Than 3 miles
10. Figure A-10. - Ceilings Less Than 1000 feet or Visibility Less Than 2 miles
11. Figure A-11. - Ceilings Less Than 200 feet or Visibility Less Than 1/2 mile
12. Figure A-12. - Temperature Less Than or Equal to 40°F, Relative Humidity Greater Than or Equal to 80 Percent, and Precipitation
13. Figure A-13. - Precipitation Not Freezing and Temperature Greater Than or Equal to 20°F But Less Than or Equal to 40°F
14. Figure A-14. - Fog or Mist and Temperature Greater Than or Equal to 20°F But Less Than or Equal to 40°F
15. Figure A-15. - Drizzle and Temperature Greater Than or Equal to 20°F But Less Than or Equal t 40°F
16. Figure A-16. - Probability of Icing at 1500 feet
17. Figure A-17. - Probability of Icing at 10000 feet
18. Figure A-18. - Probability of Icing at 18000 feet
19. Figure A-19. - Probability of Icing at 23000 feet

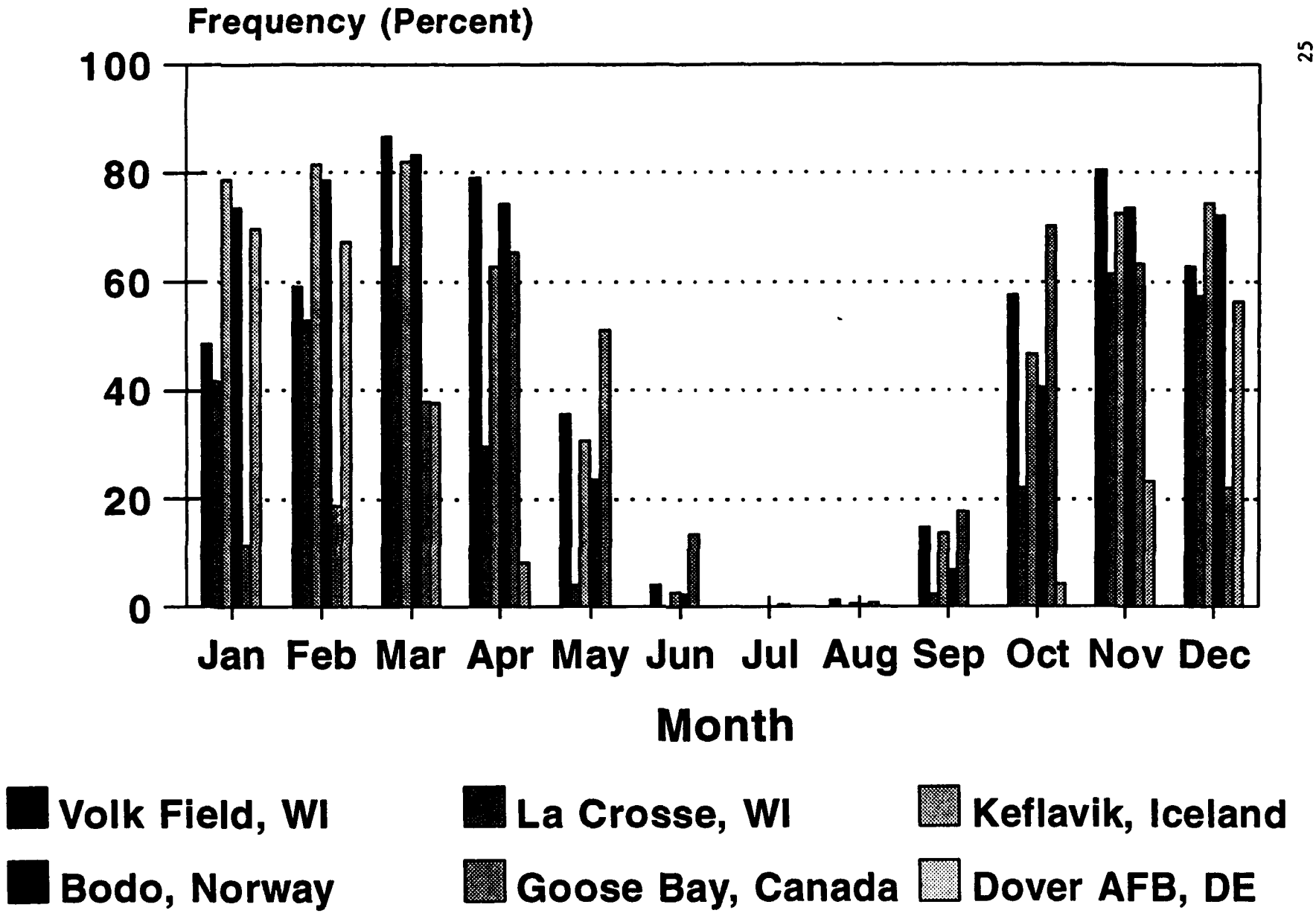

Figure A-1. Temperature Greater Than or Equal to 20 F and Less Than or Equal to 40 F

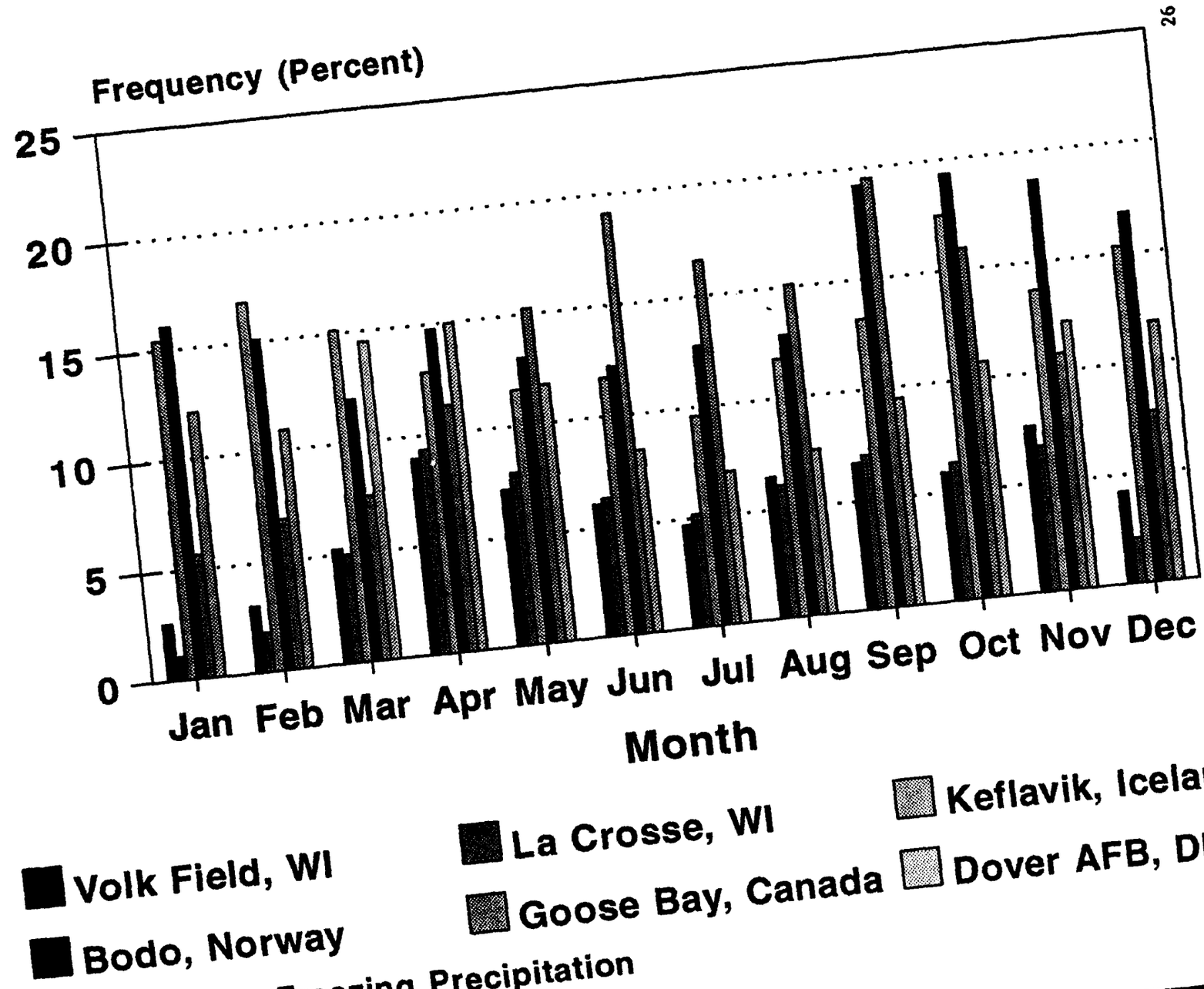

Figure A-2. Non-Freezing Precipitation

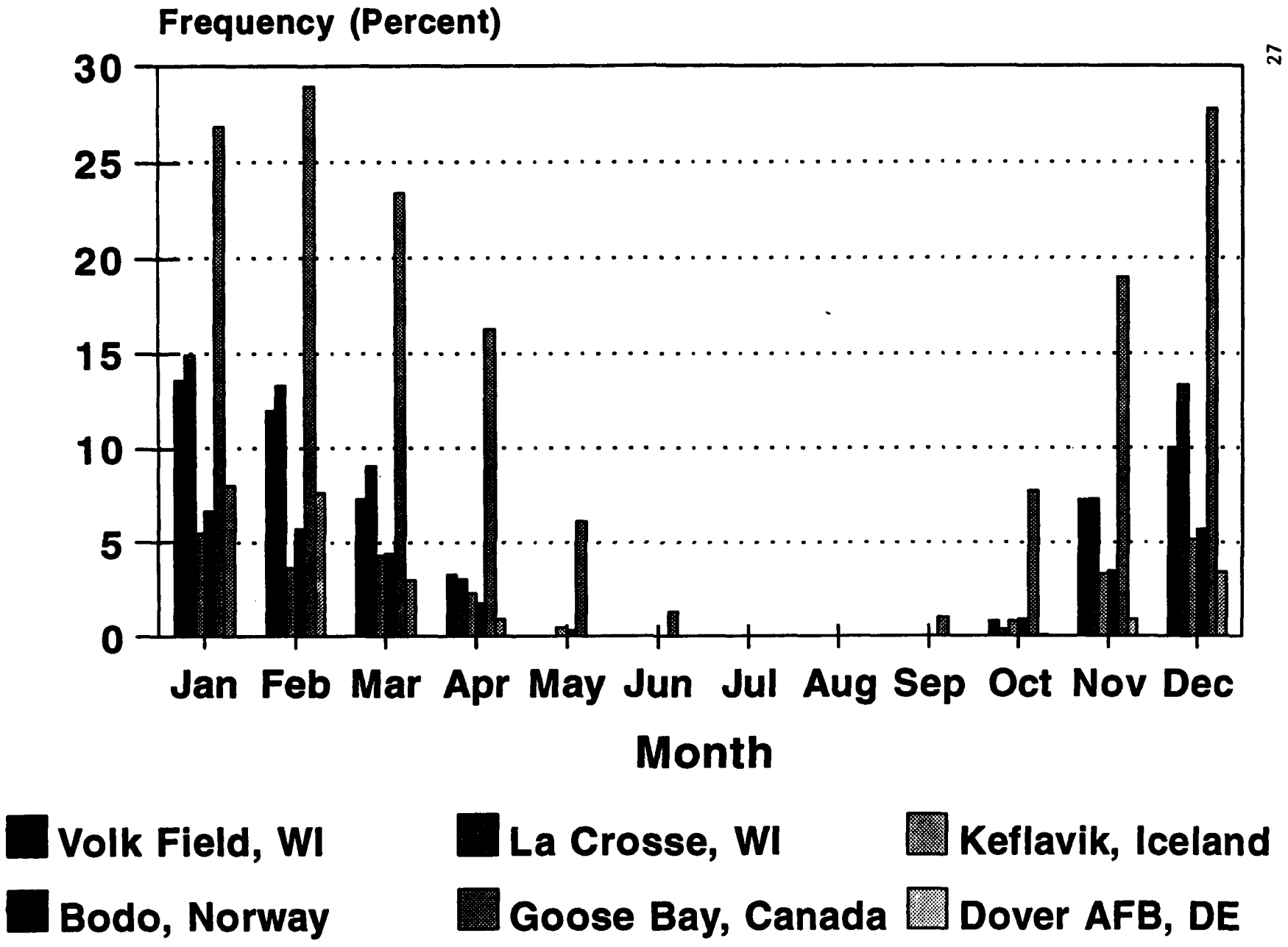

Figure A-3. Snow or Ice Pellets Not Including Freezing Precipitation

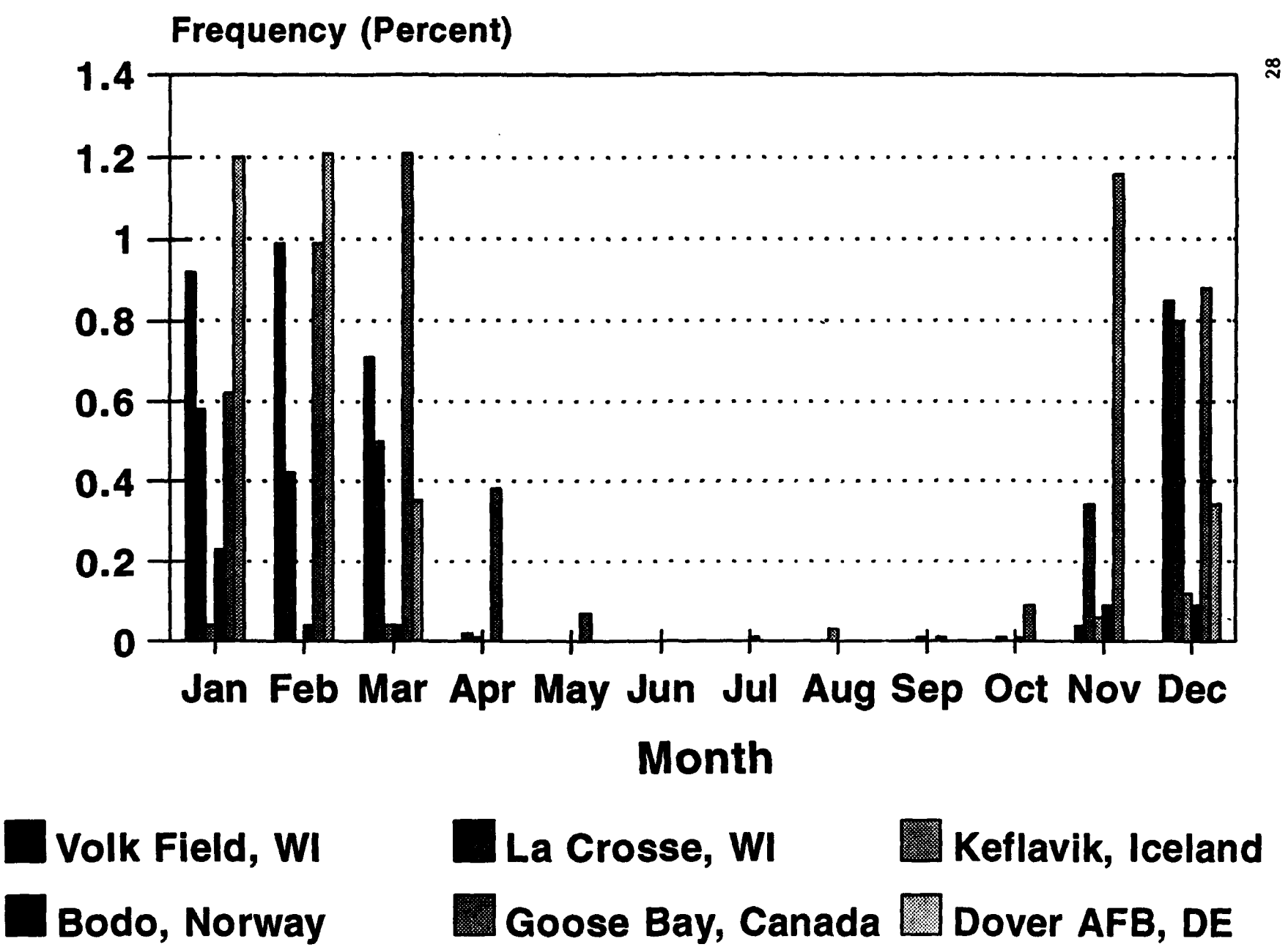

Figure A-4. Freezing Precipitation Rain or Drizzle

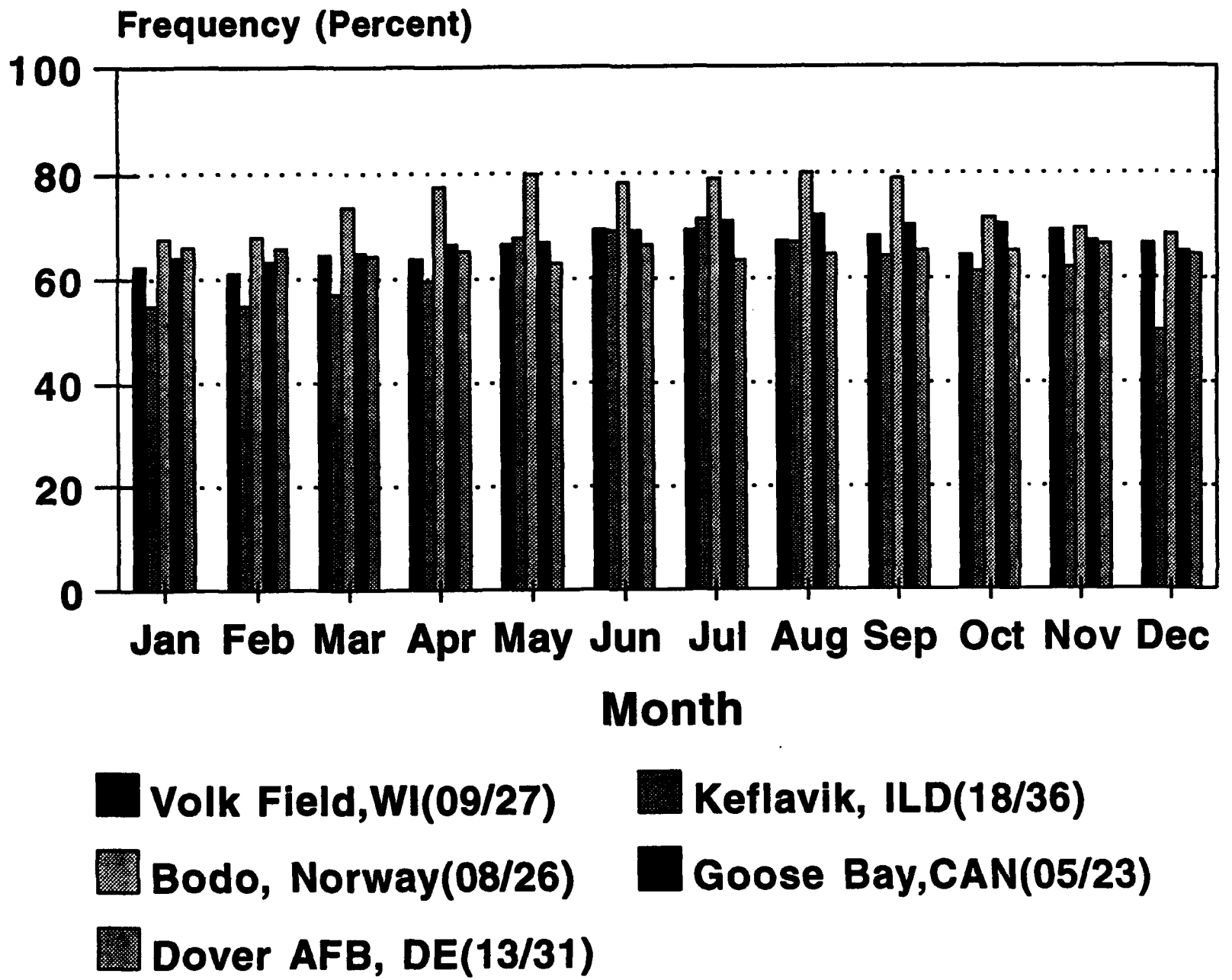

Figure A-5. Crosswinds Between 1 and 10 Knots Primary Runways

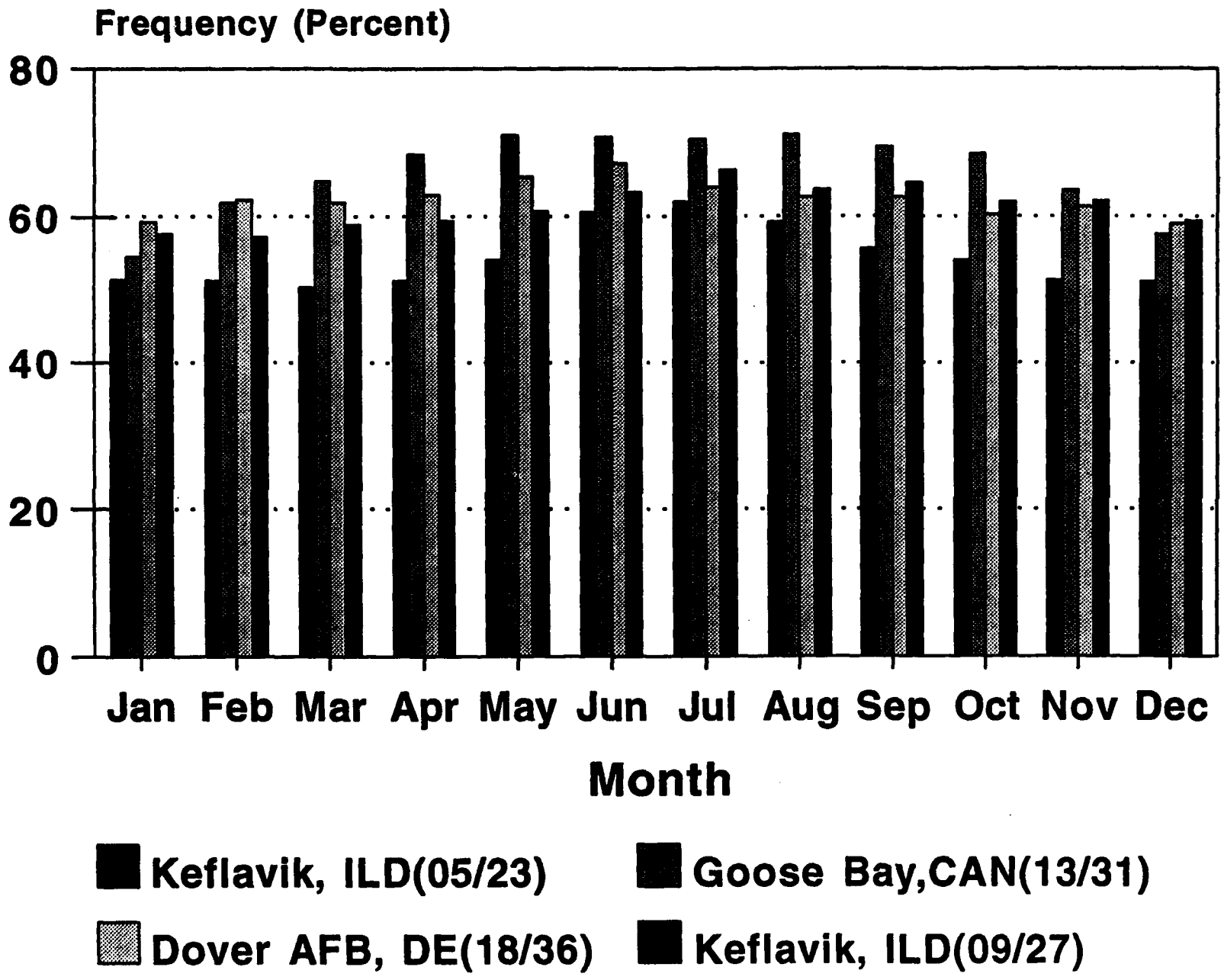

Figure A-6. Crosswinds Between 1 and 10 Knots Secondary Runways

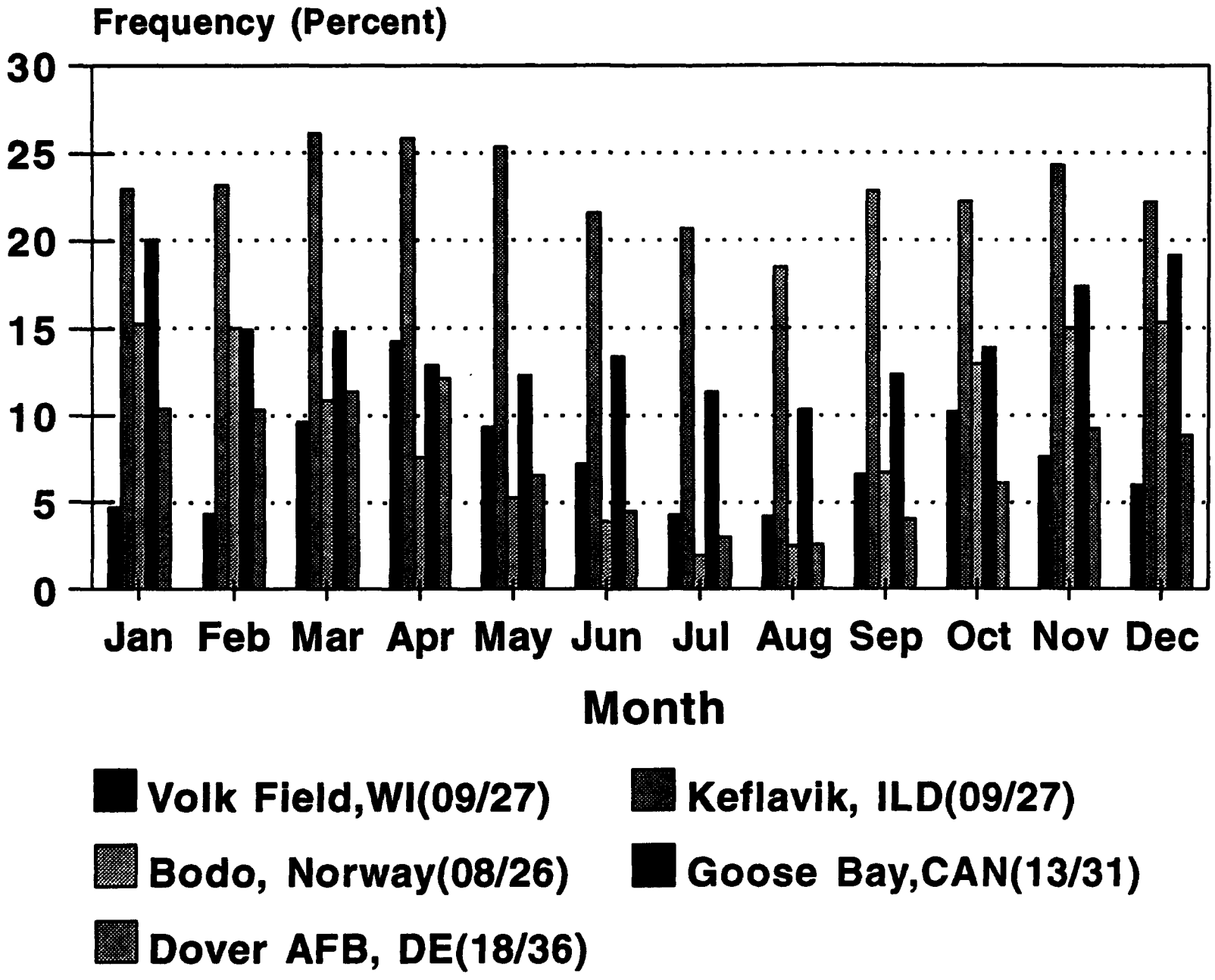

Figure A-7. Crosswinds Between 11 and 20 Knots Primary Runways

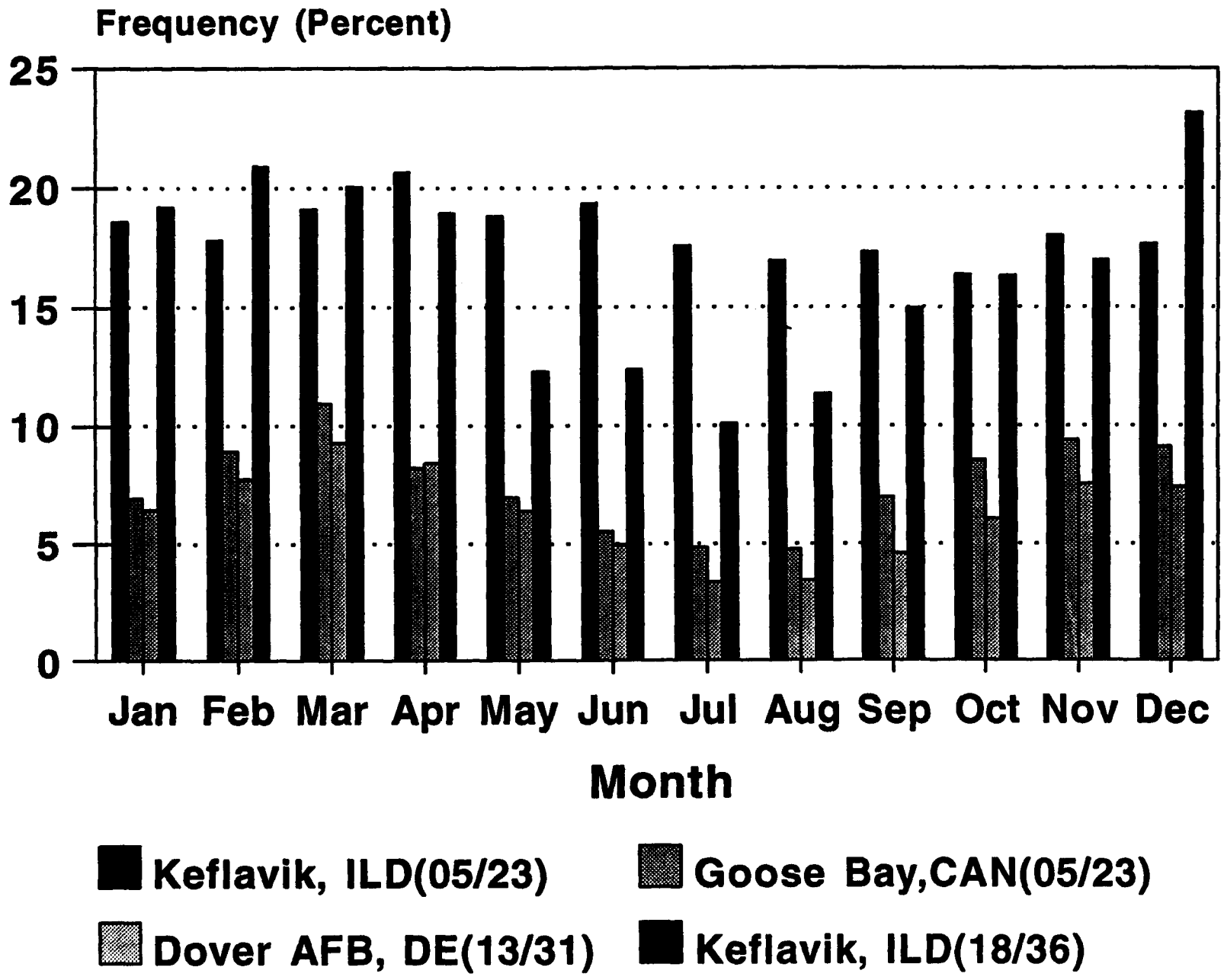

Figure A-8. Crosswinds Between 11 and 20 Knots Secondary Runways

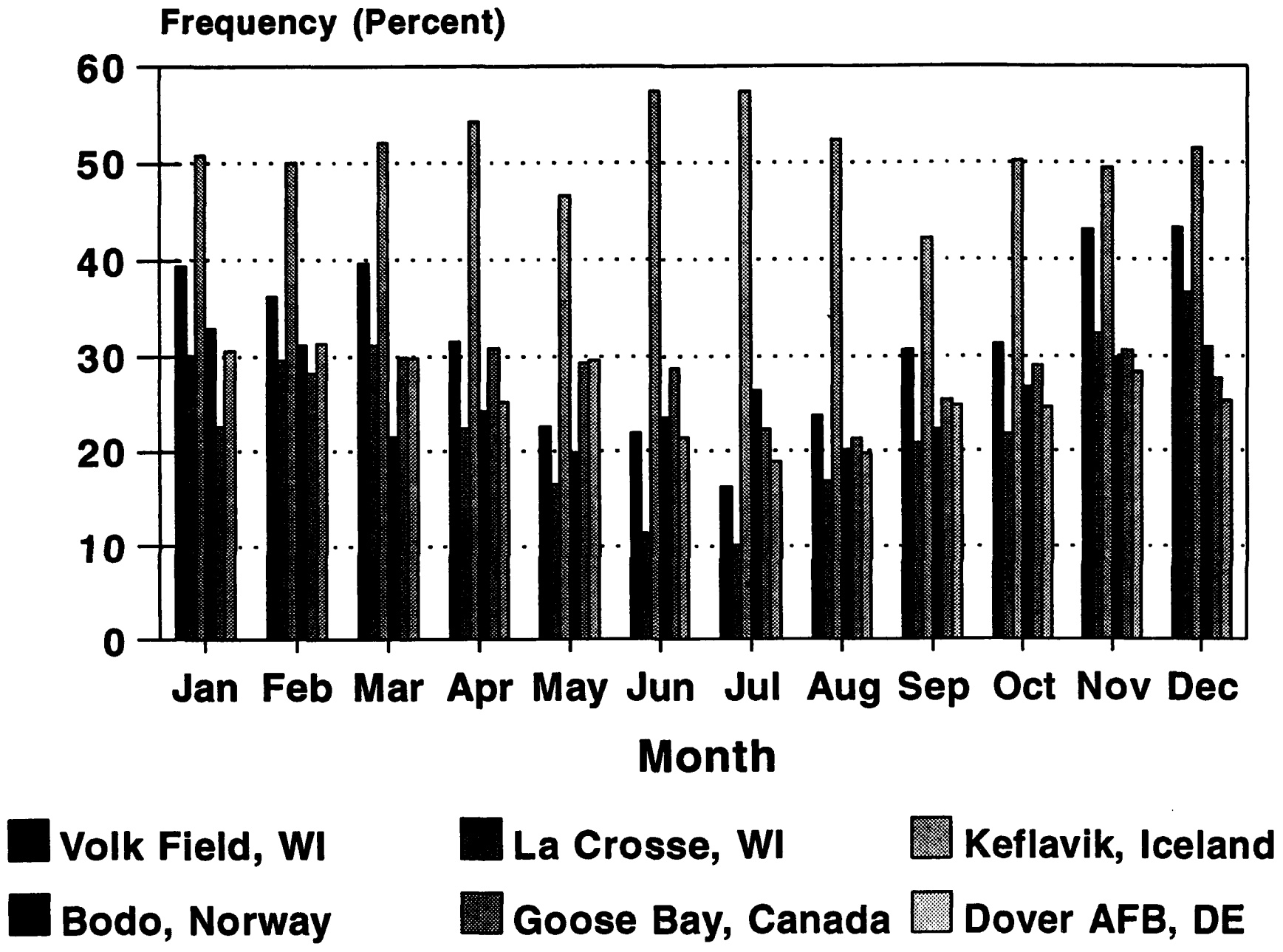

Figure A-9. Ceiling Less Than 3000 Feet or Visibility Less Than 3 Miles

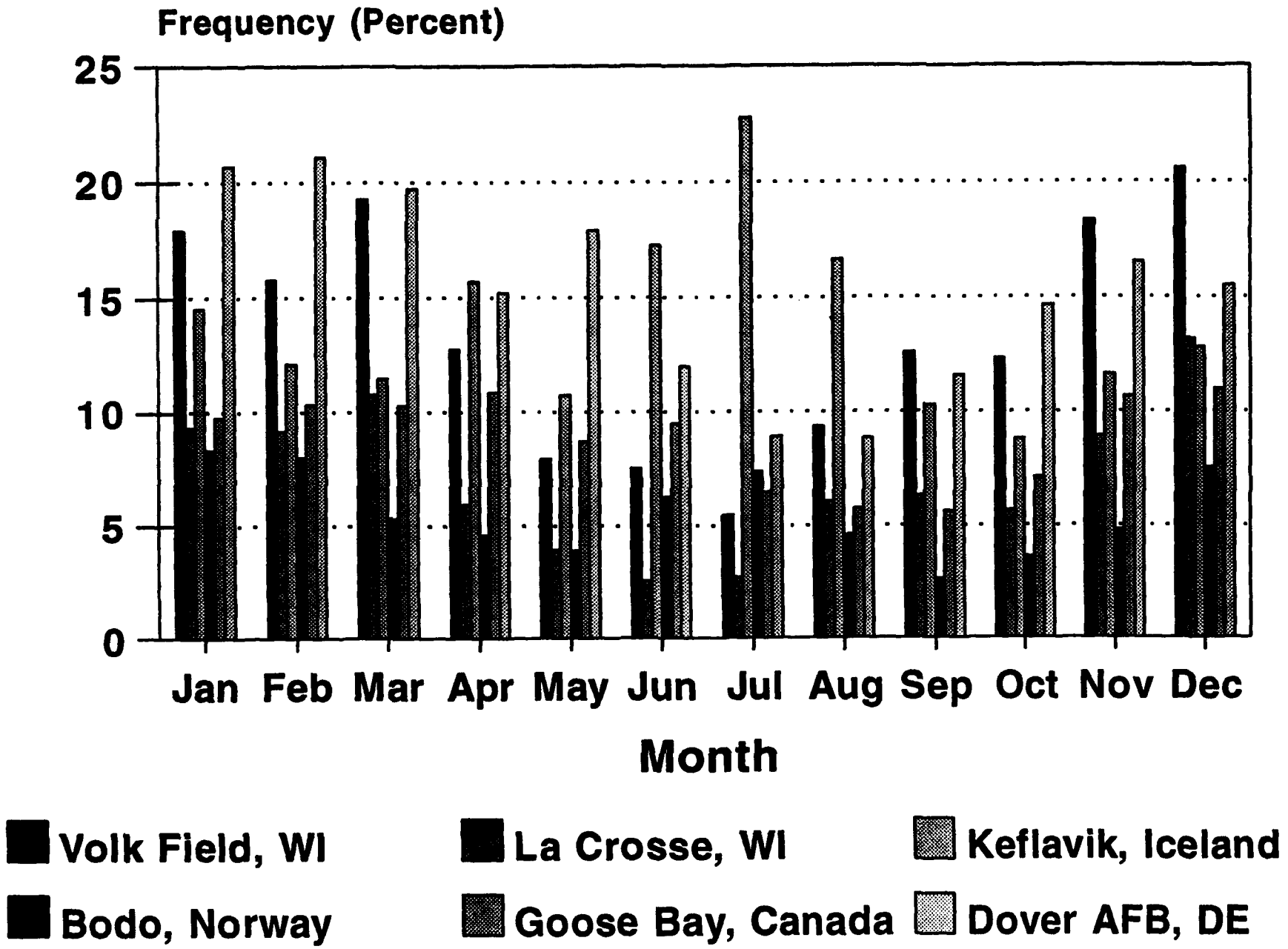

Figure A-10. Ceiling Less Than 1000 Feet or Visibility Less Than 2 Miles

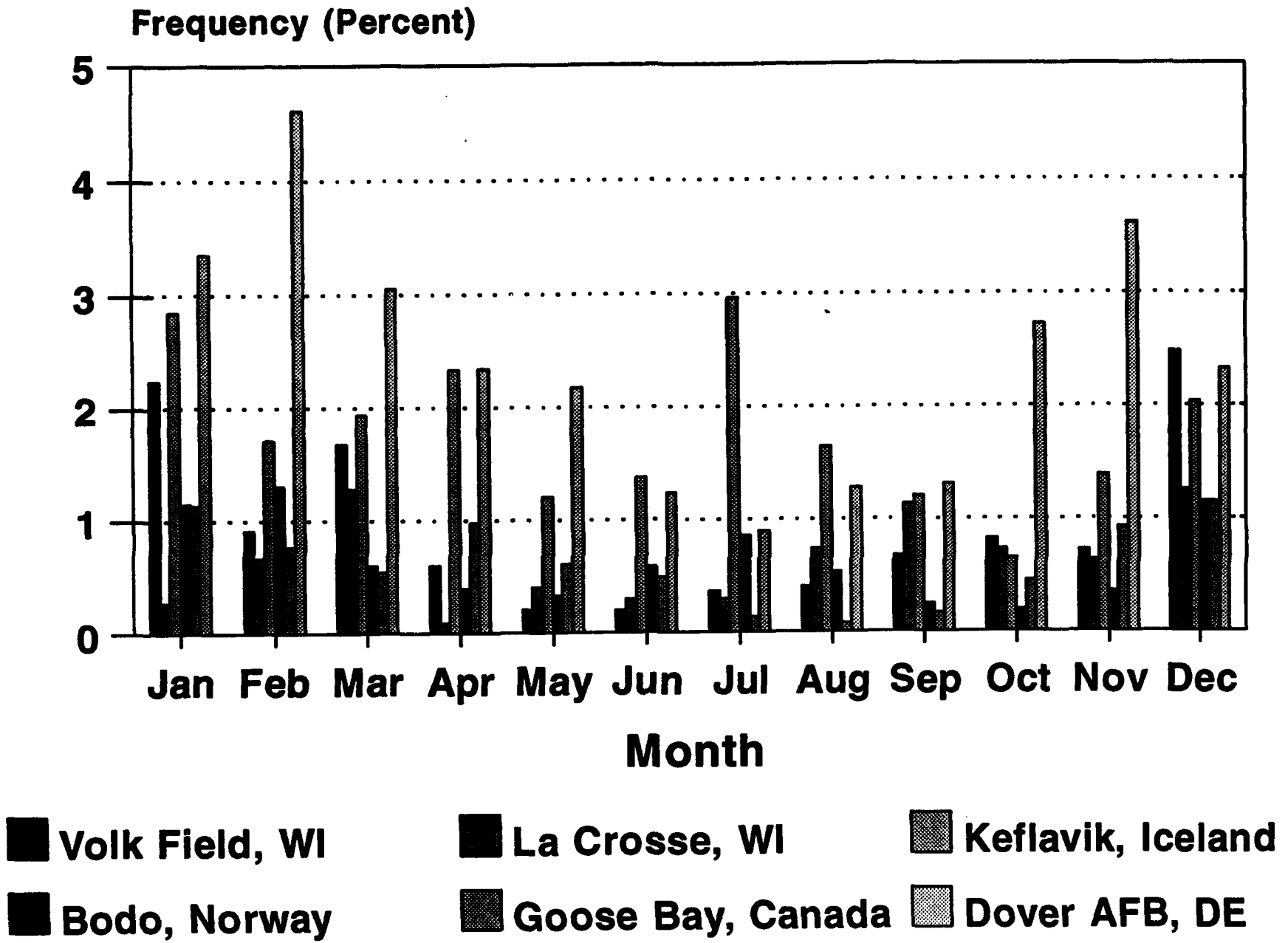

Figure A-11. Ceiling Less Than 200 Feet or Visibility Less Than 1/2 Mile

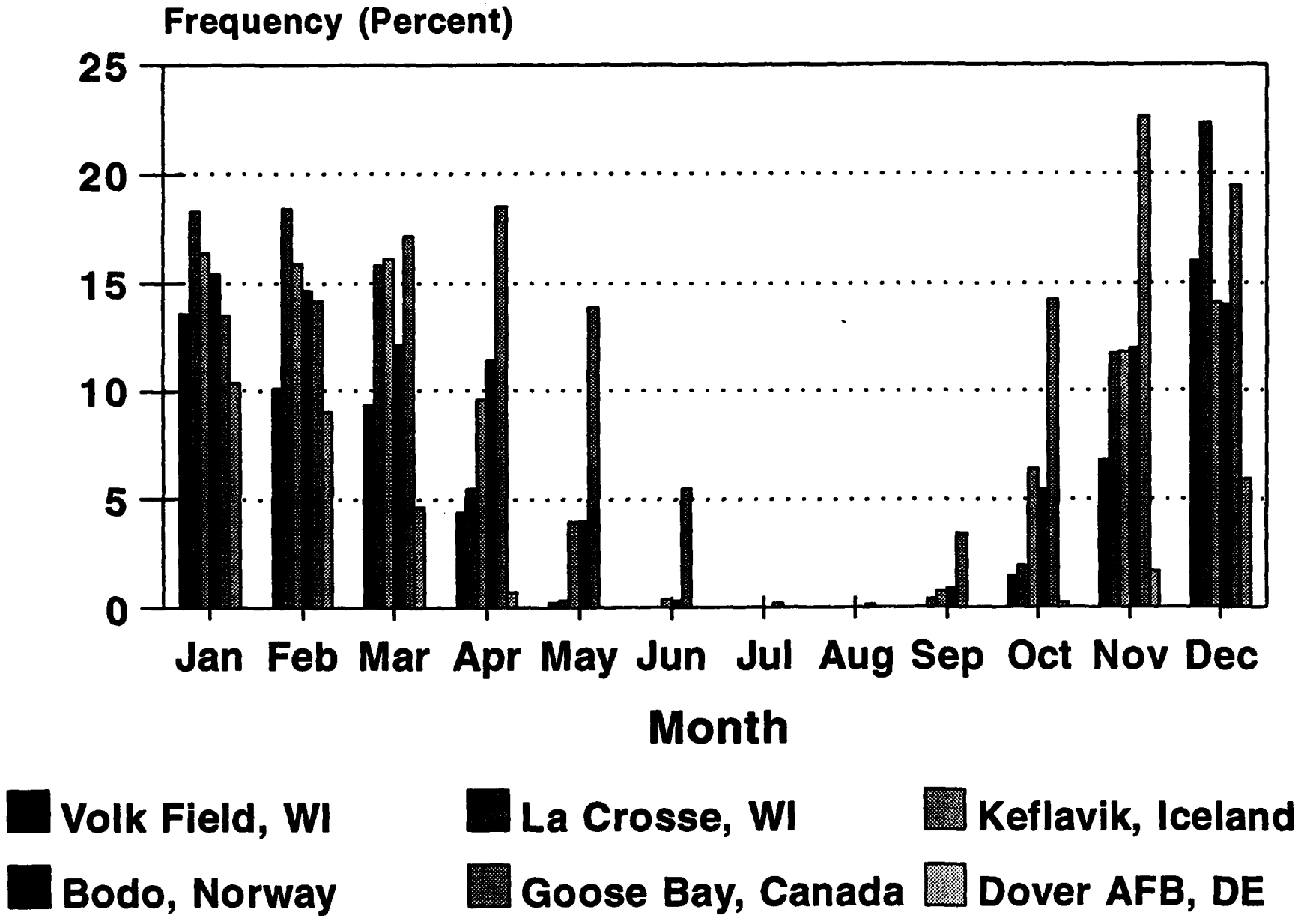

Figure A-12. Temperature Less Than or Equal to 40 F, Relative Humidity Greater Than or Equal to 80 Percent, and Precipitation

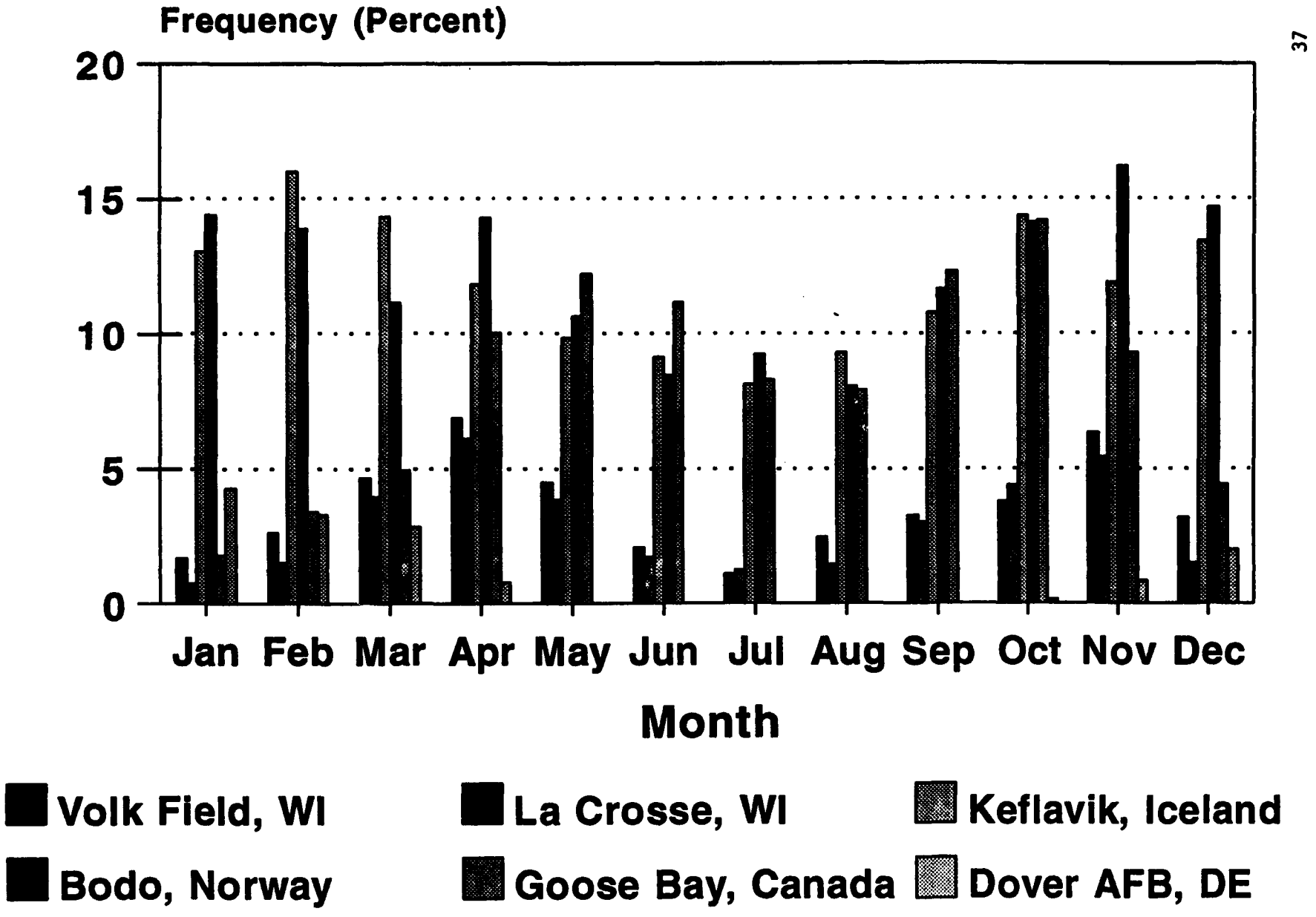

Figure A-13. Precipitation Not Freezing and Temperature Greater Than or Equal to 20 F But Less Than or Equal to 40 F

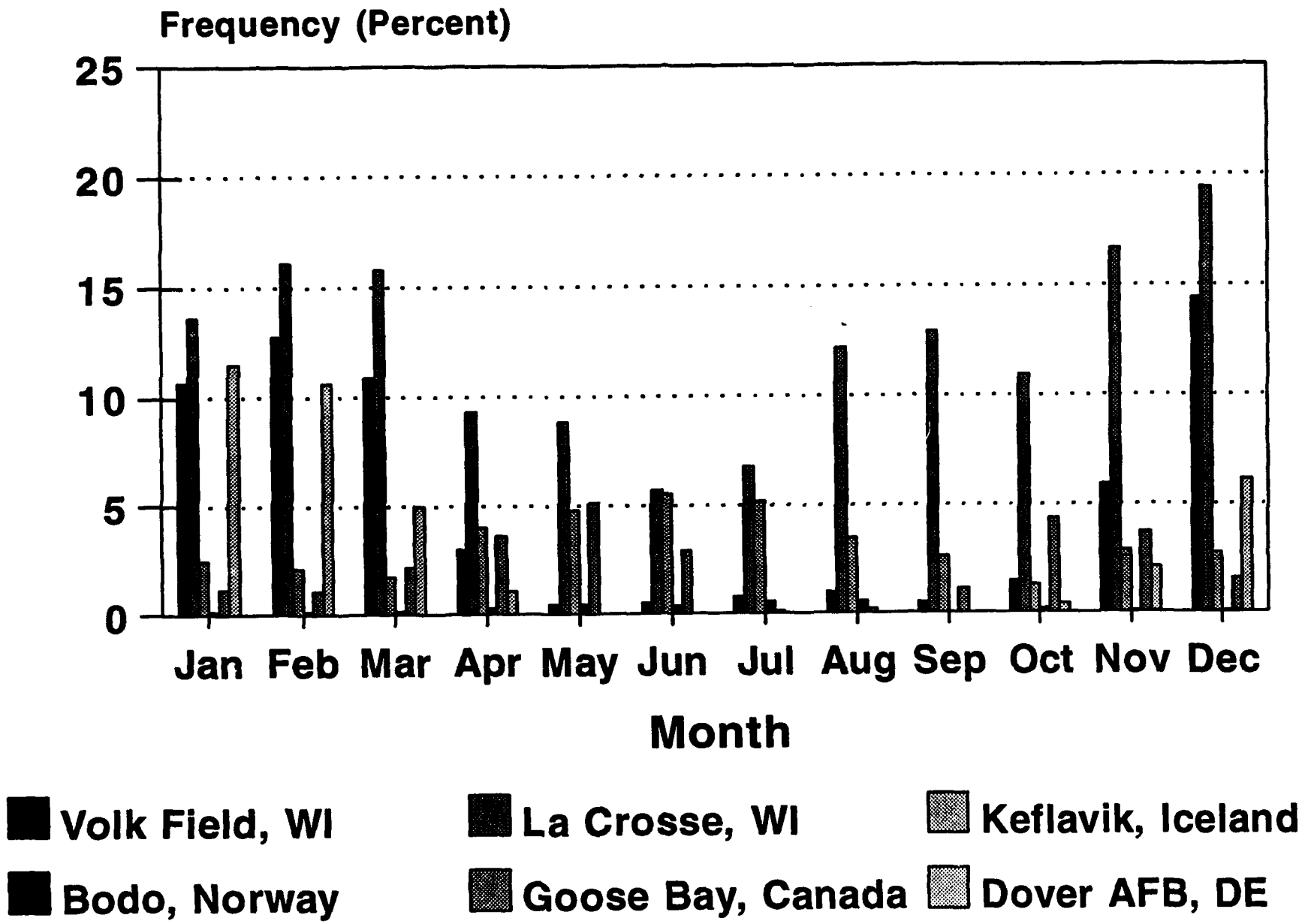

Figure A-14. Fog or Mist and Temperature Greater Than or Equal to 20 F but Less Than or Equal to 40 F

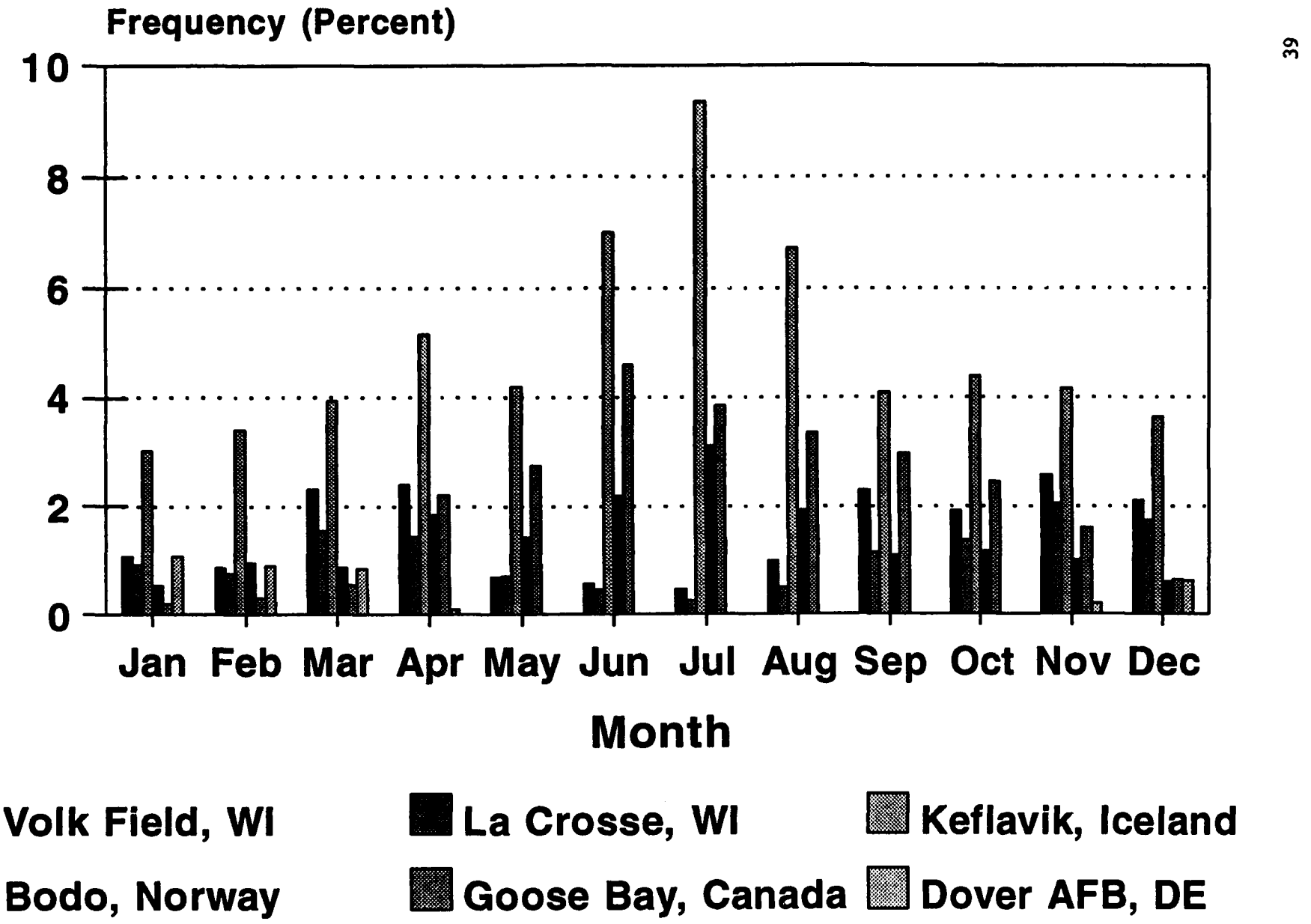

Figure A-15. Drizzle and Temperature Greater Than or Equal to 20 F but Less Than or Equal to 40 F

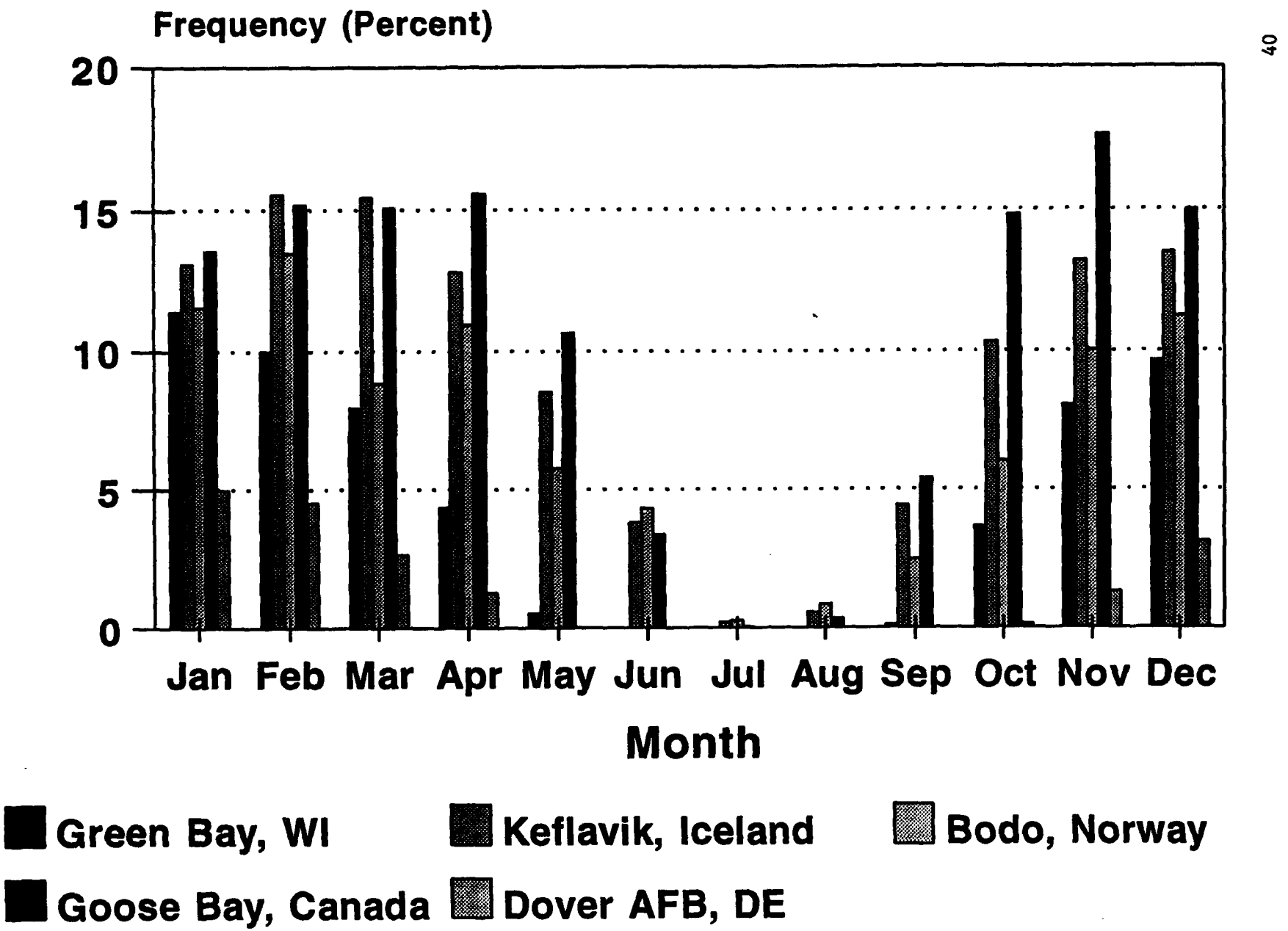

Figure A-16. Probability of Icing at 1500 Feet

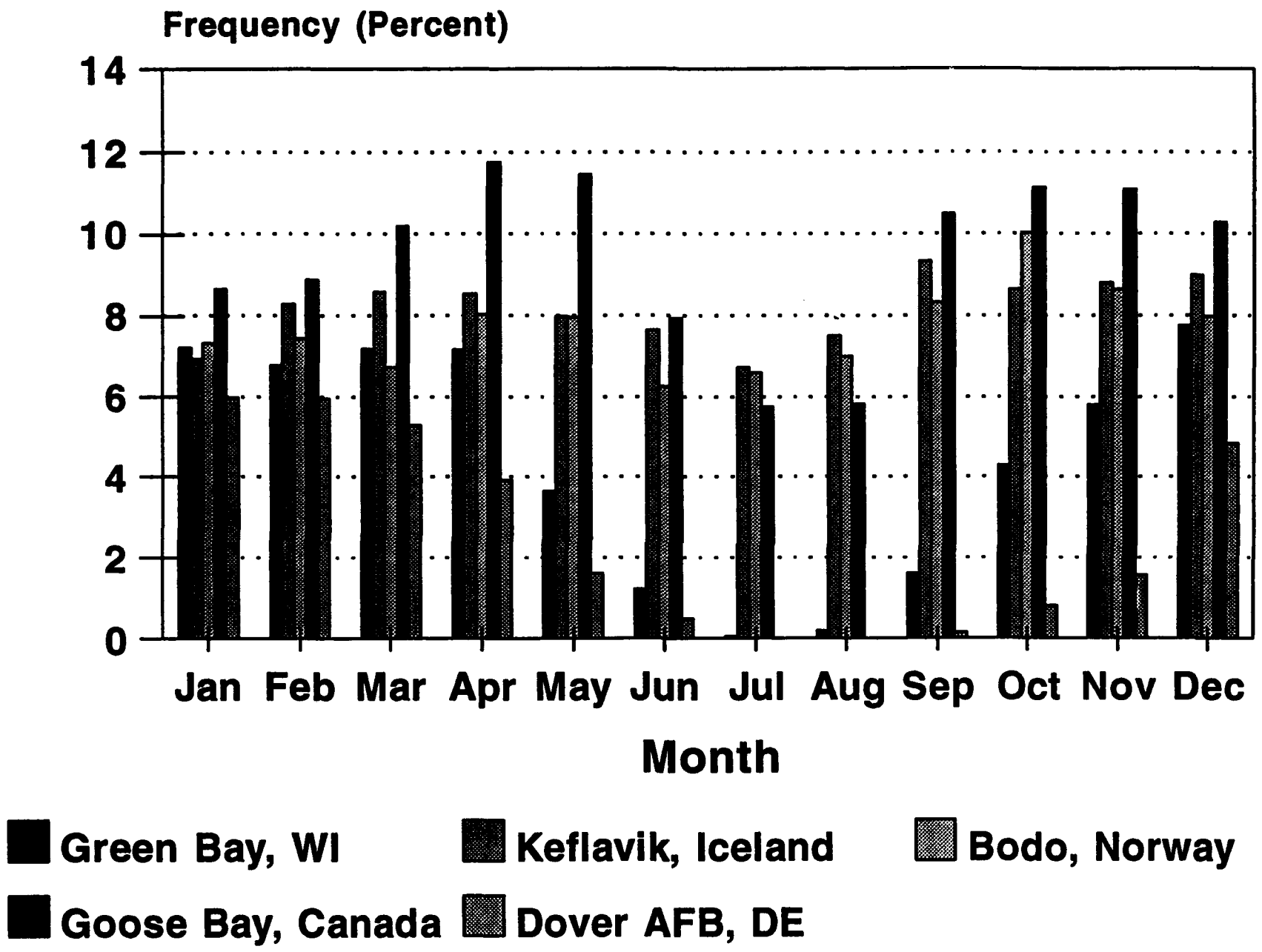

Figure A-17. Probability of Icing at 10,000 Feet

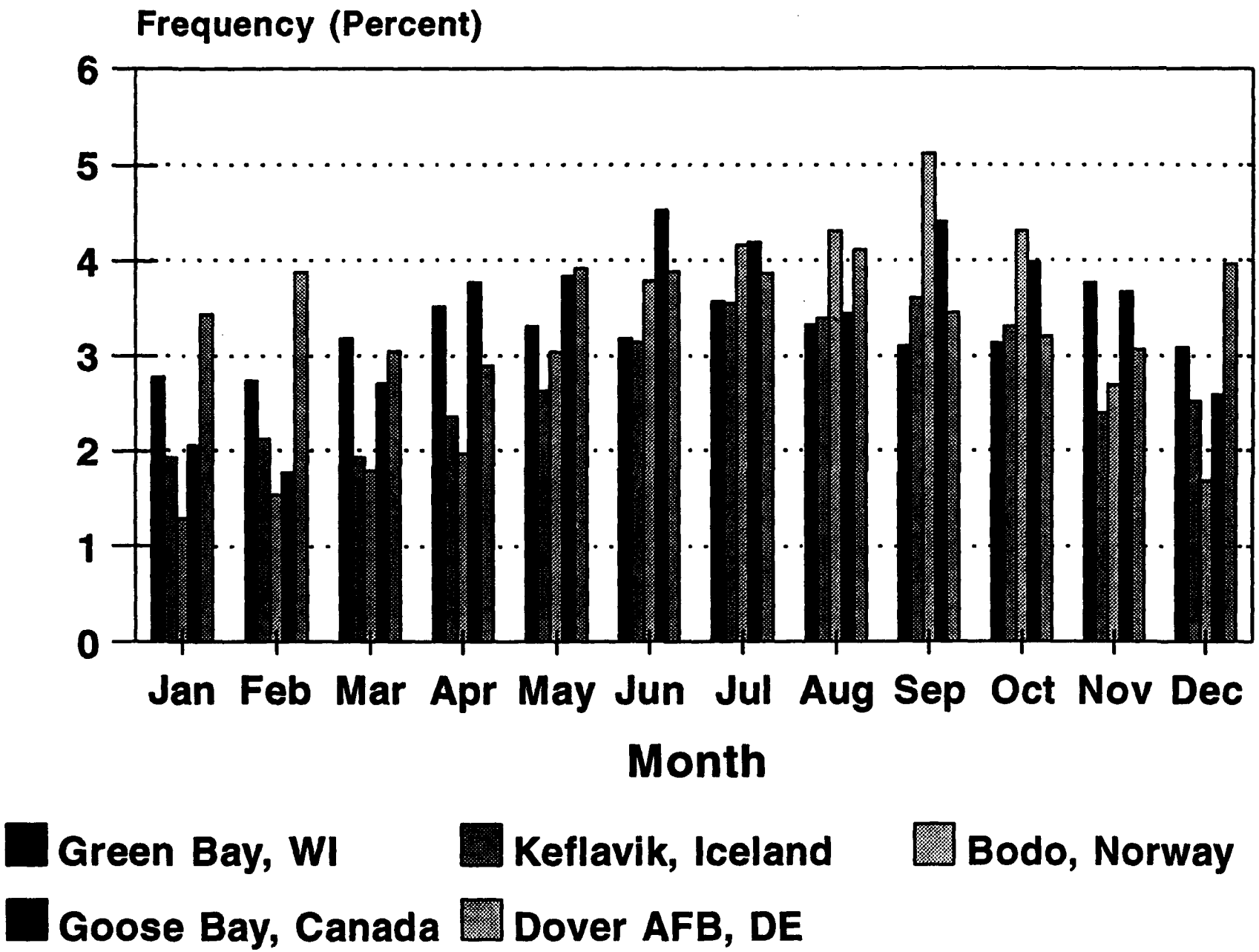

Figure A-18. Probability of Icing at 18,000 Feet

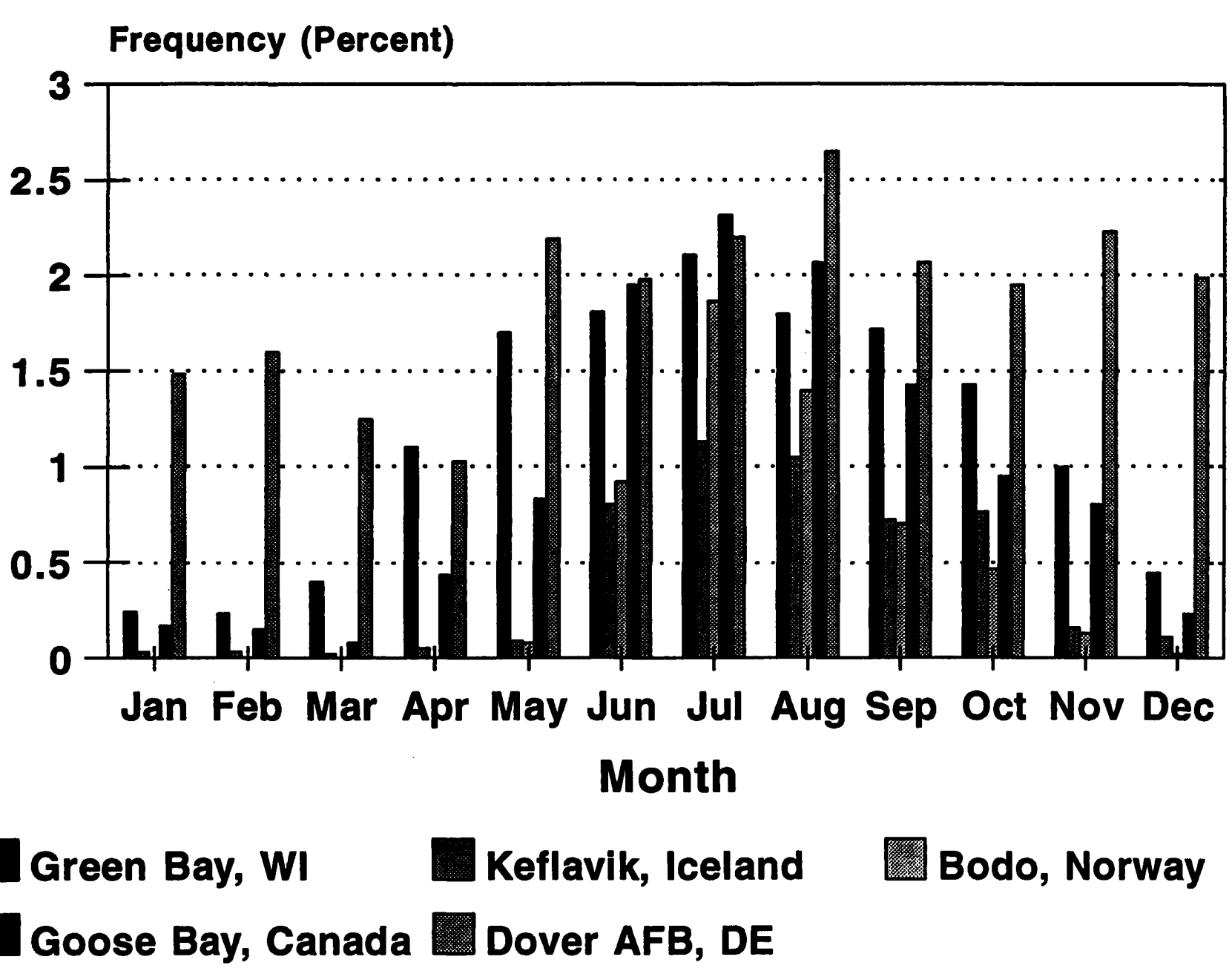

Figure A-19. Probability of Icing at 23,000 Feet

Individual weather element rankings. Stations are ranked by an average percentage frequency (1 - highest, 5 - lowest). The average monthly percentage frequency (total seasonal percentage frequency divided by 3) follows each location. Any location where the percentage frequency for each month comprising the season equals zero is automatically ranked fifth.

1. Temperature GTE 20°F and LTE 40°F (see Figure A-1).

   a) Spring rankings:

      1 - Volk Field, Wisconsin [67.21%]; (La Crosse [32.22%])
      2 - Bodo, Norway [60.33%]
      3 - Keflavik, Iceland [58.54%]
      4 - Goose Bay, Canada [51.52%]
      5 - Dover AFB Delaware [15.38%]

   b) Summer rankings:

      1 - Goose Bay, Canada [4.89%]
      2 - Volk Field, Wisconsin [1.82%]; (La Crosse [0.04%])
      3 - Keflavik, Iceland [1.09%]
      4 - Bodo, Norway [0.94%]
      5 - Dover AFB Delaware [0.01%]

   c) Fall rankings:

      1 - Volk Field, Wisconsin [50.93%]; (La Crosse [28.56%])
      2 - Goose Bay, Canada [50.42%]
      3 - Keflavik, Iceland [44.27%]
      4 - Bodo, Norway [40.30%]
      5 - Dover AFB Delaware [9.11%]

   d) Winter rankings:

      1 - Keflavik, Iceland [78.26%]
      2 - Bodo, Norway [74.81%]
      3 - Dover AFB Delaware [64.49%]
      4 - Volk Field, Wisconsin [56.87%]; (La Crosse [50.17%])
      5 - Goose Bay, Canada [17.31%]

2. Frequent exposure to rain, snow, and freezing rain.

Non-Freezing Precipitation (see Figure A-2).

1) Spring rankings:

1 - Dover AFB Delaware [13.78%]
2 - Bodo, Norway [13.29%]
3 - Keflavik, Iceland [13.29%]
4 - Goose Bay, Canada [11.37%]
5 - Volk Field, Wisconsin [7.11%]; (La Crosse [7.42%])

2) Summer rankings:

1 - Goose Bay, Canada [16.97%]
2 - Bodo, Norway [12.66%]
3 - Keflavik, Iceland [11.07%]
4 - Dover AFB Delaware [7.59%]
5 - Volk Field, Wisconsin [5.75%]; (La Crosse [5.83%])

3) Fall rankings:

1 - Bodo, Norway [19.10%]
2 - Goose Bay, Canada [15.44%]
3 - Keflavik, Iceland [14.85%]
4 - Dover AFB Delaware [10.83%]
5 - Volk Field, Wisconsin [6.73%]; (La Crosse [6.66%])

4) Winter rankings:

1 - Bodo, Norway [16.01%]
2 - Keflavik, Iceland [15.87%]
3 - Dover AFB Delaware [11.64%]
4 - Goose Bay, Canada [6.76%]
5 - Volk Field, Wisconsin [3.28%]; (La Crosse [1.64%])

Snow or Ice Pellets (see Figure A-3).

1) Spring rankings:

1 - Goose Bay, Canada [15.28%]
2 - Volk Field, Wisconsin [3.52%]; (La Crosse [4.03%])
3 - Keflavik, Iceland [2.33%]
4 - Bodo, Norway [2.12%]
5 - Dover AFB Delaware [1.29%]

2) Summer rankings:

1 - Goose Bay, Canada [0.44%]
2 - Dover AFB Delaware [0.0%]* and Keflavik, Iceland [0.0%]*
3 - Bodo, Norway [0.0%]** and Volk Field, Wisconsin [0.0%]**; (La Crosse [0.02%])

3) Fall rankings:

1 - Goose Bay, Canada [9.25%]
2 - Volk Field, Wisconsin [2.66%]; (La Crosse [2.53%])
3 - Bodo, Norway [1.44%]
4 - Keflavik, Iceland [1.38%]
5 - Dover AFB Delaware [0.32%]

* 0.01% Frequency of Occurrence of element over the season
** 0.0% Frequency of Occurrence of element over the season

4) Winter rankings:

1 - Goose Bay, Canada [27.86%]
2 - Volk Field, Wisconsin [11.88%]; (La Crosse [13.88%])
3 - Dover AFB Delaware [6.32%]
4 - Bodo, Norway [5.99%]
5 - Keflavik, Iceland [4.69%]

Freezing Precipitation (see Figure A-4).

1) Spring rankings:

1 - Goose Bay, Canada [0.55%]
2 - Volk Field, Wisconsin [0.24%]; (La Crosse [0.17%])
3 - Dover AFB Delaware [0.12%]
4 - Keflavik, Iceland [0.02%]
5 - Bodo, Norway [0.01%]

2) Summer rankings:

1 - Keflavik, Iceland [0.01%]
2 - Bodo, Norway [0.0%]*
3 - Dover AFB Delaware [0.0%]**, Goose Bay, Canada [0.0%]** and Volk Field, Wisconsin [0.0%]**; (La Crosse [0.0%])**

3) Fall rankings:

1 - Goose Bay, Canada [0.42%]
2 - Bodo, Norway [0.03%]
3 - Keflavik, Iceland [0.02%]
4 - Volk Field, Wisconsin [0.01%]; (La Crosse [0.12%])
5 - Dover AFB Delaware [0.0%]

4) Winter rankings:

1 - Volk Field, Wisconsin [0.92%]; (La Crosse [0.60%])
2 - Dover AFB Delaware [0.92%]
3 - Goose Bay, Canada [0.83%]
4 - Bodo, Norway [0.12%]
5 - Keflavik, Iceland [0.05%]

* 0.01% Frequency of Occurrence of element over the season
** 0.0% Frequency of Occurrence of element over the season

Rank computations for frequent exposure to rain, sleet, snow, and freezing precipitation. (A - Non Freezing Precipitation, B - Snow or Ice Pellets, C - Freezing Precipitation). Ties in the Total column are resolved in the following manner: By isolating the *least occurring element* and selecting the site with the highest percent frequency for the element as the higher ranking location. Note: For this particular computation, C is lowest percent frequency element.

Spring	**A**	**B**	**C**	**Total**	**Rank**
Keflavik	3	3	4	10	4
Bodo	2	4	5	11	5
Goose Bay	4	1	1	6	1
Volk Field	5	2	2	9	2
Dover AFB	1	5	3	9	3

Summer	**A**	**B**	**C**	**Total**	**Rank**
Keflavik	3	2	1	6	1
Bodo	2	5	2	9	3
Goose Bay	1	1	5	7	2
Volk Field	5	5	5	15	5
Dover AFB	4	2	5	11	4

Fall	**A**	**B**	**C**	**Total**	**Rank**
Keflavik	3	4	3	10	3
Bodo	1	3	2	6	2
Goose Bay	2	1	1	4	1
Volk Field	5	2	4	11	4
Dover AFB	4	5	5	14	5

Winter	**A**	**B**	**C**	**Total**	**Rank**
Keflavik	2	5	5	12	5
Bodo	1	4	4	9	4
Goose Bay	4	1	3	8	3
Volk Field	5	2	1	8	1
Dover AFB	3	3	2	8	2

3. Slippery taxiways and runways with a runway condition rating as low as six. The weather elements of Non-Freezing Precipitation, Snow or Ice Pellets, and Freezing Precipitation are presented above. Ranking computations are the same as presented above.

4. Crosswind components up to 20 kts during taxi, takeoff, and landing. True runway headings follow the location in parentheses.

Crosswinds between 1 and 10 kts (see Figures A-5 & A-6).

1) Spring rankings:

1- Bodo (08-26) [77.08%]
2 - Goose Bay (05-23) [66.15%]
3 - Volk Field (09-27) [65.02%]
4 - Dover AFB (13-31) [64.22%]
5 - Keflavik (18-36) [61.53%]

2) Summer rankings:

1 - Bodo (08-26) [79.21%]
2 - Goose Bay (05-23) [70.77%]
3 - Keflavik (18-36) [69.13%]
4 - Volk Field (09-27) [68.66%]
5 - Dover AFB (13-31) [64.8%]

3) Fall rankings:

1 - Bodo (08-26) [73.35%]
2 - Goose Bay (05-23) [69.31%]
3 - Volk Field (09-27) [67.28%]
4 - Dover AFB (13-31) [65.76%]
5 - Keflavik (18-36) [62.51%]

4) Winter rankings:

1 - Bodo (08-26) [68.08%]
2 - Dover AFB (13-31) [65.55%]
3 - Goose Bay (05-23) [64.2%]
4 - Volk Field (09-27) [63.36%]
5 - Keflavik (18-36) [53.28%]

Crosswinds between 11 and 20 kts (see Figures A-7 & A-8).

1) Spring rankings:

1 - Keflavik (18-36) [25.75%]
2 - Bodo (08-26) [15.23%]
3 - Goose Bay (13-31) [13.35%]
4 - Volk Field (09-27) [11.08%]
5 - Dover AFB (18-36) [10.04%]

2) Summer rankings:

1 - Keflavik (18-36) [20.26%]
2 - Goose Bay (13-31) [11.7%]
3 - Bodo (08-26) [7.91%]
4 - Volk Field (09-27) [5.22%]
5 - Dover AFB (18-36) [3.33%]

3) Fall rankings:

1 - Keflavik (18-36) [23.13%]
2 - Goose Bay (13-31) [14.57%]
3 - Volk Field (09-27) [8.13%]
4 - Dover AFB (18-36) [6.46%]
5 - Bodo (08-26) [2.78%]

4) Winter rankings:

1 - Keflavik (18-36) [22.78%]
2 - Goose Bay (13-31) [18.04%]
3 - Bodo (08-26) [11.57%]
4 - Dover AFB (18-36) [9.87%]
5 - Volk Field (09-27) [4.98%]

c) Composite rank computations for crosswind components up to 20 kts during taxi, takeoff, and landing. (**A** - Crosswinds between 1 and 10 kts; **B** - Crosswinds between 11 and 20 kts) Note: **B** is the lower percent frequency element.

Spring	**A**	**B**	**Total**	**Rank**
Keflavik	5	1	6	3
Bodo	1	2	3	1
Goose Bay	2	3	5	2
Volk Field	3	4	7	4
Dover AFB	4	5	9	5

Summer	**A**	**B**	**Total**	**Rank**
Keflavik	3	1	4	1
Bodo	1	3	4	3
Goose Bay	2	2	4	2
Volk Field	4	4	8	4
Dover AFB	5	5	10	5

Fall	**A**	**B**	**Total**	**Rank**
Keflavik	5	1	6	2
Bodo	1	5	6	4
Goose Bay	2	2	4	1
Volk Field	3	3	6	3
Dover AFB	4	4	8	5

Winter	**A**	**B**	**Total**	**Rank**
Keflavik	5	1	6	3
Bodo	1	3	4	1
Goose Bay	3	2	5	2
Volk Field	4	5	9	5
Dover AFB	2	4	6	4

5. High surface winds over salt water. Because of the distance from any significant source of sea salts, Volk Field and Goose Bay are automatically ranked fifth. Average monthly percentage from which the wind blows for Dover (E-S), Bodo (NNW-SSW), and Goose Bay (NNW-SSW) follow the location.

a) Spring rankings:

1 - Keflavik [24.67%]
2 - Bodo [15.33%]
3 - Dover AFB [28.0%] *
4 - Goose Bay and Volk Field

b) Summer rankings:

1 - Bodo [39.33%]
2 - Keflavik [34.0%]
3 - Dover AFB [28.0%]
4 - Goose Bay and Volk Field

c) Fall rankings:

1 - Bodo [33.67%]
2 - Keflavik [25.67%]
3 - Dover AFB [23.3%]
4 - Goose Bay and Volk Field

d) Winter rankings:

1 - Keflavik [23.67%]
2 - Bodo [19.67%]
3 - Dover AFB [16.7%]
4 - Goose Bay and Volk Field

6. Instrument meteorological conditions for inflight evaluation.

Ceilings LT 3000 feet or visibility LT 3 miles (see Figure A-9).

1) Spring rankings.

1 - Keflavik, Iceland [50.99%]
2 - Volk Field, Wisconsin [31.32%]; (La Crosse [23.38%])
3 - Goose Bay, Canada [30.04%]
4 - Dover AFB Delaware [28.28%]
5 - Bodo, Norway [21.88%]

2) Summer rankings:

1 - Keflavik, Iceland [55.73%]
2 - Goose Bay, Canada [24.15%]
3 - Bodo, Norway [23.38%]
4 - Volk Field, Wisconsin [20.61%]; (La Crosse [12.68%])
5 - Dover AFB Delaware [20.07%]

3) Fall rankings:

1 - Keflavik, Iceland [47.33%]
2 - Volk Field, Wisconsin [35.04%]; (La Crosse [25.03%])
3 - Goose Bay, Canada [28.39%]
4 - Bodo, Norway [26.31%]
5 - Dover AFB Delaware [18.0%]

4) Winter rankings:

1 - Keflavik, Iceland [50.83%]
2 - Volk Field, Wisconsin [39.66%]; (La Crosse [32.16%])
3 - Bodo, Norway [31.73%]
4 - Dover AFB Delaware [29.1%]
5 - Goose Bay, Canada [26.22%]

Ceilings LT 1000 feet or visibility LT 2 miles (see Figure A-10).

1) Spring rankings:

1 - Dover AFB Delaware [17.65%]
2 - Volk Field, Wisconsin [13.34%]; (La Crosse [6.88%])
3 - Keflavik, Iceland [12.67%]
4 - Goose Bay, Canada [9.96%]
5 - Bodo, Norway [4.60%]

2) Summer rankings:

1 - Keflavik, Iceland [18.9%]
2 - Dover AFB Delaware [9.94%]
3 - Volk Field, Wisconsin [7.46%]; (La Crosse [3.77%])
4 - Goose Bay, Canada [7.23%]
5 - Bodo, Norway [6.05%]

3) Fall rankings:

1 - Volk Field, Wisconsin [14.44%]; (La Crosse [6.96%])
2 - Dover AFB Delaware [14.29%]
3 - Keflavik, Iceland [10.26%]
4 - Goose Bay, Canada [7.80%]
5 - Bodo, Norway [3.67%]

4) Winter rankings:

1 - Dover AFB Delaware [19.1%]
2 - Volk Field, Wisconsin [18.12%]; (La Crosse [10.57%])
3 - Keflavik, Iceland [13.18%]
4 - Goose Bay, Canada [10.38%]
5 - Bodo, Norway [7.97%]

Ceilings LT 200 feet or visibility LT 1/2 miles (see Figure A-11).

1) Spring rankings:

1 - Dover AFB Delaware [2.53%]
2 - Keflavik, Iceland [1.83%]
3 - Volk Field, Wisconsin [0.83%]; (La Crosse [0.59%])
4 - Goose Bay, Canada [0.71%]
5 - Bodo, Norway [0.44%]

2) Summer rankings:

1 - Keflavik, Iceland [2.0%]
2 - Dover AFB Delaware [1.13%]
3 - Bodo, Norway [0.65%]
4 - Volk Field, Wisconsin [0.32%]; (La Crosse [0.45%])
5 - Goose Bay, Canada [0.23%]

3) Fall rankings:

1 - Dover AFB Delaware [2.55%]
2 - Keflavik, Iceland [1.08%]
3 - Volk Field, Wisconsin [0.74%]; (La Crosse [0.83%])
4 - Goose Bay, Canada [0.51%]
5 - Bodo, Norway [0.26%]

4) Winter rankings:

1 - Dover AFB Delaware [3.43%]
2 - Keflavik, Iceland [2.2%]
3 - Volk Field, Wisconsin [1.88%]; (La Crosse [0.73%])
4 - Bodo, Norway [1.19%]
5 - Goose Bay, Canada [0.84%]

d) Rank computations for Instrument Meteorological Condition (IMC) for inflight evaluation. (A - Ceiling LT 3000 ft or Visibility LT 3 Miles, B - Ceiling LT 1000 ft or Visibility LT 1 Mile, C - Ceiling LT 200 ft or Visibility LT 1/2 Mile) Note: C is the lowest percent frequency element.

Spring	**A**	**B**	**C**	**Total**	**Rank**
Keflavik	1	3	2	6	2
Bodo	5	5	5	15	5
Goose Bay	3	4	4	11	4
Volk Field	2	2	3	7	3
Dover AFB	4	1	1	6	1

Summer	**A**	**B**	**C**	**Total**	**Rank**
Keflavik	1	1	1	3	1
Bodo	3	5	3	11	3
Goose Bay	2	4	5	11	5
Volk Field	4	3	4	11	4
Dover AFB	5	2	2	9	2

Fall	**A**	**B**	**C**	**Total**	**Rank**
Keflavik	1	3	2	6	1
Bodo	4	5	5	14	5
Goose Bay	3	4	4	11	4
Volk Field	2	1	3	6	2
Dover AFB	5	2	1	8	3

Winter	**A**	**B**	**C**	**Total**	**Rank**
Keflavik	1	3	2	6	2
Bodo	3	5	4	12	4
Goose Bay	5	4	5	14	5
Volk Field	2	2	3	7	3
Dover AFB	4	1	1	6	1

7. Temperature/humidity combinations conducive to airframe/engine icing during ground operations.

Temperature LTE 40°F, Relative Humidity GTE 80%, and Precipitation (see Figure A-12).

1) Spring rankings:

1 - Goose Bay, Canada [16.52%]
2 - Keflavik, Iceland [9.89%]
3 - Bodo, Norway [9.18%]
4 - Volk Field, Wisconsin [4.64%]; (La Crosse [7.19%])
5 - Dover AFB Delaware [1.78%]

2) Summer rankings:

1 - Goose Bay, Canada [1.93%]
2 - Keflavik, Iceland [0.13%]
3 - Bodo, Norway [0.11%]
4 - Dover AFB Delaware [0.0%] and volk Field [0.0%]; (La Crosse [0.0%])

3) Fall rankings:

1 - Goose Bay, Canada [13.42%]
2 - Keflavik, Iceland [6.33%]
3 - Bodo, Norway [6.08%]
4 - Volk Field, Wisconsin [2.78%]; (La Crosse [4.68%])
5 - Dover AFB Delaware [0.64%]

4) Winter rankings:

1 - Goose Bay, Canada [15.73%]
2 - Keflavik, Iceland [15.48%]
3 - Bodo, Norway [14.7%]
4 - Volk Field, Wisconsin [13.25%]; (La Crosse [19.68%])
5 - Dover AFB Delaware [8.43%]

Precipitation Not Freezing and Temperature GTE 20^{o}F, But LTE 40^{o}F (see Figure A-13).

1) Spring rankings:

1 - Bodo, Norway [12.04%]
2 - Keflavik, Iceland [12.0%]
3 - Goose Bay, Canada [9.05%]
4 - Volk Field, Wisconsin [1.86%]; (La Crosse [4.62%])
5 - Dover AFB Delaware [1.2%]

2) Summer rankings:

1 - Goose Bay, Canada [9.14%]
2 - Keflavik, Iceland [8.86%]
3 - Bodo, Norway [8.58%]
4 - Volk Field, Wisconsin [1.86%]; (La Crosse [1.46%])
5 - Dover AFB Delaware [0.0%]

3) Fall rankings:

1 - Bodo, Norway [14.0%]
2 - Keflavik, Iceland [12.36%]
3 - Goose Bay, Canada [11.93%]
4 - Volk Field, Wisconsin [4.44%]; (La Crosse [4.26%])
5 - Dover AFB Delaware [0.33%]

4) Winter rankings:

1 - Bodo, Norway [14.33%]
2 - Keflavik, Iceland [14.16%]
3 - Goose Bay, Canada [3.18%]
4 - Dover AFB Delaware [3.17%]
5 - Volk Field, Wisconsin [2.5%]; (La Crosse [1.26%])

Fog or Mist and Temperature GTE 20°F, But LTE 40°F (see Figure A-14).

1) Spring rankings:

1 - Volk Field, Wisconsin [4.77%]; (La Crosse [11.34%])
2 - Goose Bay, Canada [3.6%]
3 - Keflavik, Iceland [3.48%]
4 - Dover AFB Delaware [2.02%]
5 - Bodo, Norway [0.29%]

2) Summer rankings:

1 - Keflavik, Iceland [4.7%]
2 - Goose Bay, Canada [1.05%]
3 - Volk Field, Wisconsin [0.74%]; (La Crosse [8.21%])
4 - Bodo, Norway [0.49%]
5 - Dover AFB Delaware [0.0%]

3) Fall rankings:

1 - Goose Bay, Canada [3.02%]
2 - Volk Field, Wisconsin [2.61%]; (La Crosse [13.52%])
3 - Keflavik, Iceland [2.24%]
4 - Dover AFB Delaware [0.84%]
5 - Bodo, Norway [0.1%]

4) Winter rankings:

1 - Volk Field, Wisconsin [12.61%]; (La Crosse [16.38%])
2 - Dover AFB Delaware [9.41%]
3 - Keflavik, Iceland [2.41%]
4 - Goose Bay Canada [1.24%]
5 - Bodo, Norway [0.13%]

Drizzle and Temperature GTE 20°F, But LTE 40°F (see Figure A-15).

1) Spring rankings:

1 - Keflavik, Iceland [4.44%]
2 - Goose Bay, Canada [1.83%]
3 - Volk Field, Wisconsin [1.79%]; (La Crosse [1.23%])
4 - Bodo, Norway [1.37%]
5 - Dover AFB Delaware [0.31%]

2) Summer rankings:

1 - Keflavik, Iceland [7.7%]
2 - Goose Bay, Canada [3.93%]
3 - Bodo, Norway [2.4%]
5 - Dover AFB Delaware [0.0%]

3) Fall rankings:

1 - Keflavik, Iceland [4.22%]
2 - Goose Bay, Canada [2.33%]
3 - Volk Field, Wisconsin [2.25%]; (La Crosse [1.51%])
4 - Bodo, Norway [1.08%]
5 - Dover AFB Delaware [0.07%]

4) Winter rankings:

1 - Keflavik, Iceland [3.36%]
2 - Volk Field, Wisconsin [1.34%]; (La Crosse [1.13%])
3 - Dover AFB Delaware [0.86%]
4 - Bodo, Norway [0.69%]
5 - Goose Bay, Canada [0.37%]

e) Rank computations for temperature/humidity combinations conducive to airframe/engine icing during ground operations. (**A** - Temperature LTE 40°F, Relative Humidity GTE 80%, and Precipitation, **B** - Precipitation Not Freezing and Temperature GTE 20°F, But LTE 40°F, **C** - Fog or Mist and Temperature GTE 20°F, But LTE 40°F, **D** - Drizzle and Temperature GTE 20°F, But LTE 40°F) Note: **D** is the lowest percent frequency element.

Spring	**A**	**B**	**C**	**D**	**Total**	**Rank**
Keflavik	2	2	3	1	8	1
Bodo	3	1	5	4	13	4
Goose Bay	1	3	2	2	8	2
Volk Field	4	4	1	3	12	3
Dover AFB	5	5	4	5	19	5

Summer	**A**	**B**	**C**	**D**	**Total**	**Rank**
Keflavik	2	2	1	1	6	1
Bodo	3	3	4	3	13	3
Goose Bay	1	1	2	2	6	2
Volk Field	5	4	3	4	16	4
Dover AFB	5	5	5	5	20	5

Fall	**A**	**B**	**C**	**D**	**Total**	**Rank**
Keflavik	2	2	3	1	8	2
Bodo	3	1	5	4	13	4
Goose Bay	1	3	1	2	7	1
Volk Field	4	4	2	3	13	3
Dover AFB	5	5	4	5	19	5

Winter	**A**	**B**	**C**	**D**	**Total**	**Rank**
Keflavik	2	2	3	1	8	1
Bodo	3	1	5	4	13	3
Goose Bay	1	3	4	5	13	4
Volk Field	4	5	1	2	12	2
Dover AFB	5	4	2	3	14	5

8. Exposure to natural inflight icing (see Figures A-16 through A-19)

a) Spring rankings:

1 - Goose Bay [29.01%]
2 - Keflavik [22.81%]
3 - Bodo [18.4%]
4 - Volk Field [14.69%]
5 - Dover AFB [9.80%]

b) Summer rankings:

1 - Goose Bay [13.94%]
2 - Bodo [13.92%]
3 - Keflavik [13.19%]
4 - Dover AFB [6.3%]
5 - Volk Field [5.76%]

c) Fall rankings:

1 - Goose Bay [28.61%]
2 - Keflavik [21.92%]
3 - Bodo [19.66%]
4 - Volk Field [12.57%]
5 - Dover AFB [6.68%]

d) Winter rankings:

1 - Goose Bay [26.17%]
2 - Keflavik [24.38%]
3 - Bodo [21.20%]
4 - Volk Field [20.77%]
5 - Dover AFB [15.87%]

APPENDIX B

Average Number of Durations Annually (Figures B-1 through B-15). All charts present the average number of times by month the weather element occurred. The bars correspond to locations starting at the top row of the legend and reading from left to right. For example, in Figure B-1 the first column for January indicates a yearly average of 15 occurrences for Volk Field, 24 occurrences for La Crosse, 52 for Keflavik, 60 for Bodo, 7 for Goose Bay, and 21 for Dover AFB. The same pattern follows for all other charts. Figures are titled as follows:

1. Figure B-1. - Temperature Greater Than or Equal to 20°F and Less Than or Equal to 40°F
2. Figure B-2. - Non-Freezing Precipitation
3. Figure B-3. - Snow or Ice Pellets Not Including Freezing Precipitation
4. Figure B-4. - Freezing Precipitation Rain or Drizzle
5. Figure B-5. - Crosswinds Between 1 and 10 Knots Primary Runways
6. Figure B-6. - Crosswinds Between 1 and 10 Knots Secondary Runways
7. Figure B-7. - Crosswinds Between 11 and 20 Knots Primary Runways
8. Figure B-8. - Crosswinds Between 11 and 20 Knots Secondary Runways
9. Figure B-9. - Ceilings Less Than 3000 Feet or Visibility Less Than 3 Miles
10. Figure B-10. - Ceilings Less Than 1000 Feet or Visibility Less Than 2 Miles
11. Figure B-11. - Ceilings Less Than 200 Feet or Visibility Less Than 1/2 Mile
12. Figure B-12. - Temperature Less Than or Equal to 40°F, Relative Humidity Greater Than or Equal to 80 Percent, and Precipitation
13. Figure B-13. - Precipitation Not Freezing and Temperature Greater Than or Equal to 20°F But Less Than or Equal to 40°F
14. Figure B-14. - Fog or Mist and Temperature Greater Than or Equal to 20°F But Less Than or Equal to 40°F
15. Figure B-15. - Drizzle and Temperature Greater Than or Equal to 20°F But Less Than or Equal to 40°F

Average Length of Durations (Figures B-16 through B-30). All charts display the average length of time by month the weather element occurred. The chart legends are read the same as in paragraph A above.

1. Figure B-16. - Temperature Greater Than or Equal to 20°F and Less Than or Equal to 40°F
2. Figure B-17. - Non-Freezing Precipitation
3. Figure B-18. - Snow or Ice Pellets Not Including Freezing Precipitation
4. Figure B-19. - Freezing Precipitation Rain or Drizzle
5. Figure B-20. - Crosswinds Between 1 and 10 Knots Primary Runways
6. Figure B-21. - Crosswinds Between 1 and 10 Knots Secondary Runways
7. Figure B-22. - Crosswinds Between 11 and 20 Knots Primary Runways
8. Figure B-23. - Crosswinds Between 11 and 20 Knots Secondary Runways
9. Figure B-24. - Ceilings Less Than 3000 Feet or Visibility Less Than 3 Miles
10. Figure B-25. - Ceilings Less Than 1000 Feet or Visibility Less Than 2 Miles
11. Figure B-26. - Ceilings Less Than 200 Feet or Visibility Less Than 1/2 Mile
12. Figure B-27. - Temperature Less Than or Equal to 40°F, Relative Humidity Greater Than or Equal to 80 Percent, and Precipitation
13. Figure B-28. - Precipitation Not Freezing and Temperature Greater Than or Equal to 20°F, But Less Than or Equal to 40°F
14. Figure B-29. - Fog or Mist and Temperature Greater Than or Equal to 20°F, But Less Than or Equal to 40°F
15. Figure B-30. - Drizzle and Temperature Greater Than or Equal to 20°F, But Less Than or Equal to 40°F

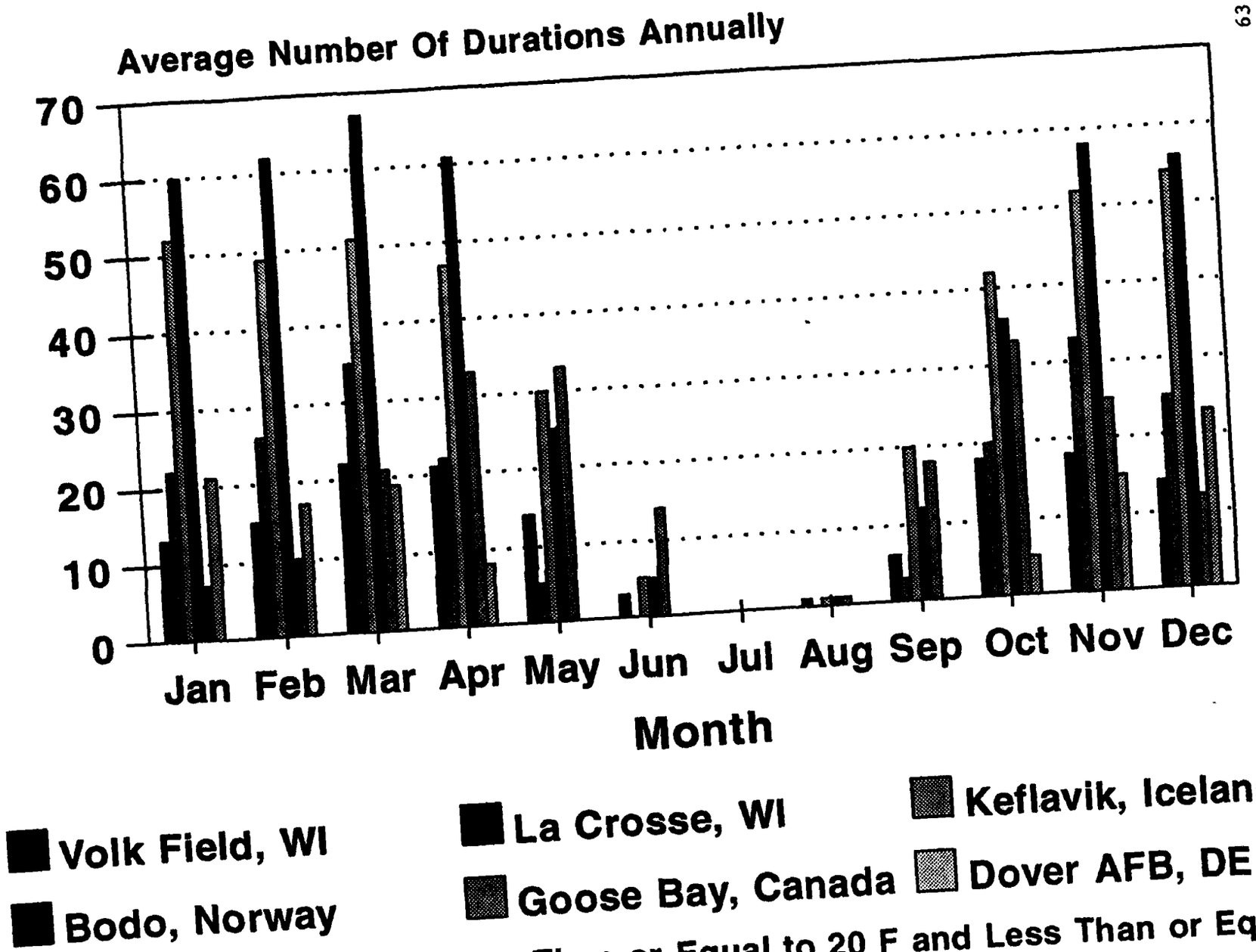

Figure B-1. Temperature Greater Than or Equal to 20 F and Less Than or Equal to 40 F

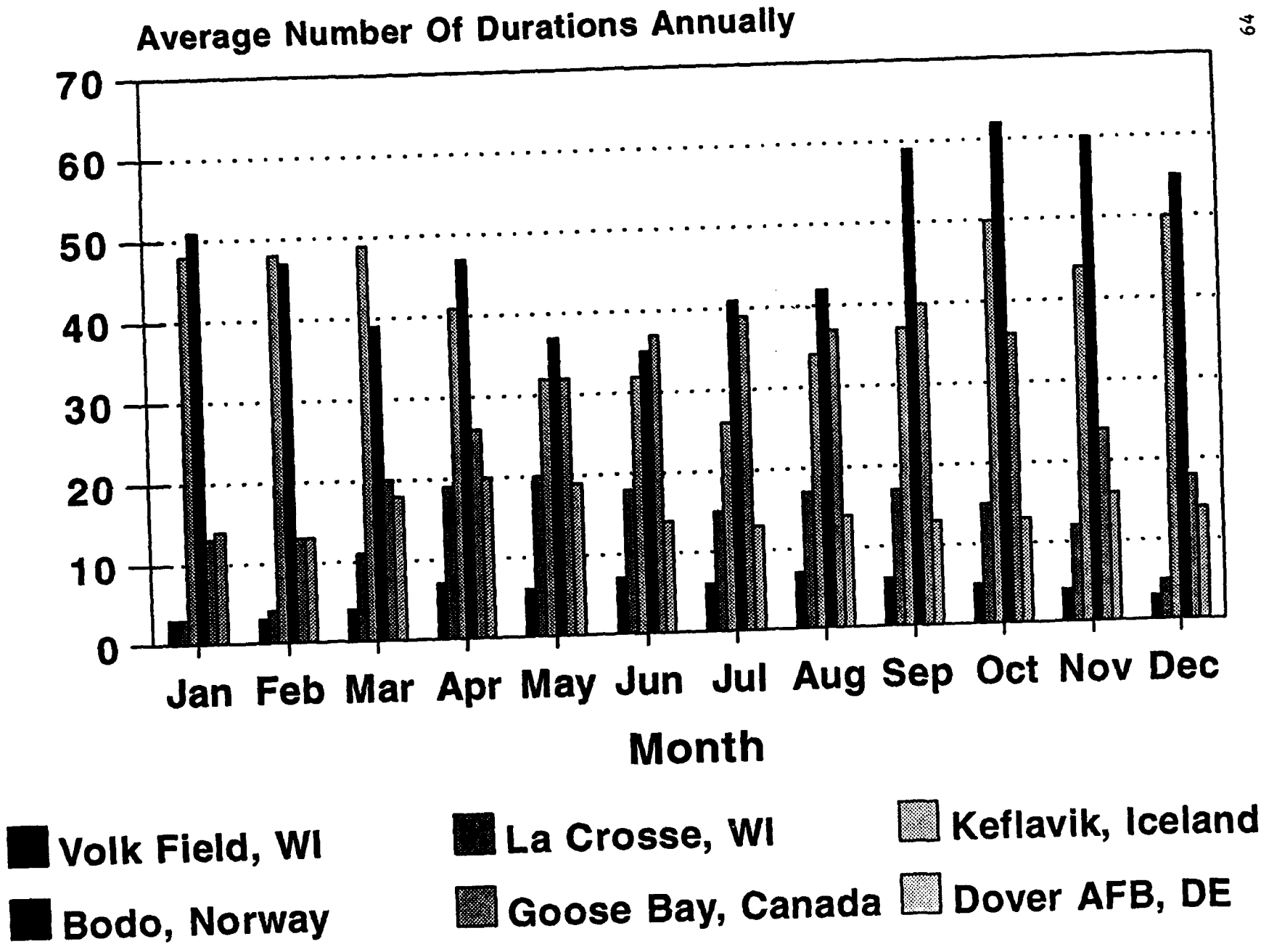

Figure B-2. Non-Freezing Precipitation

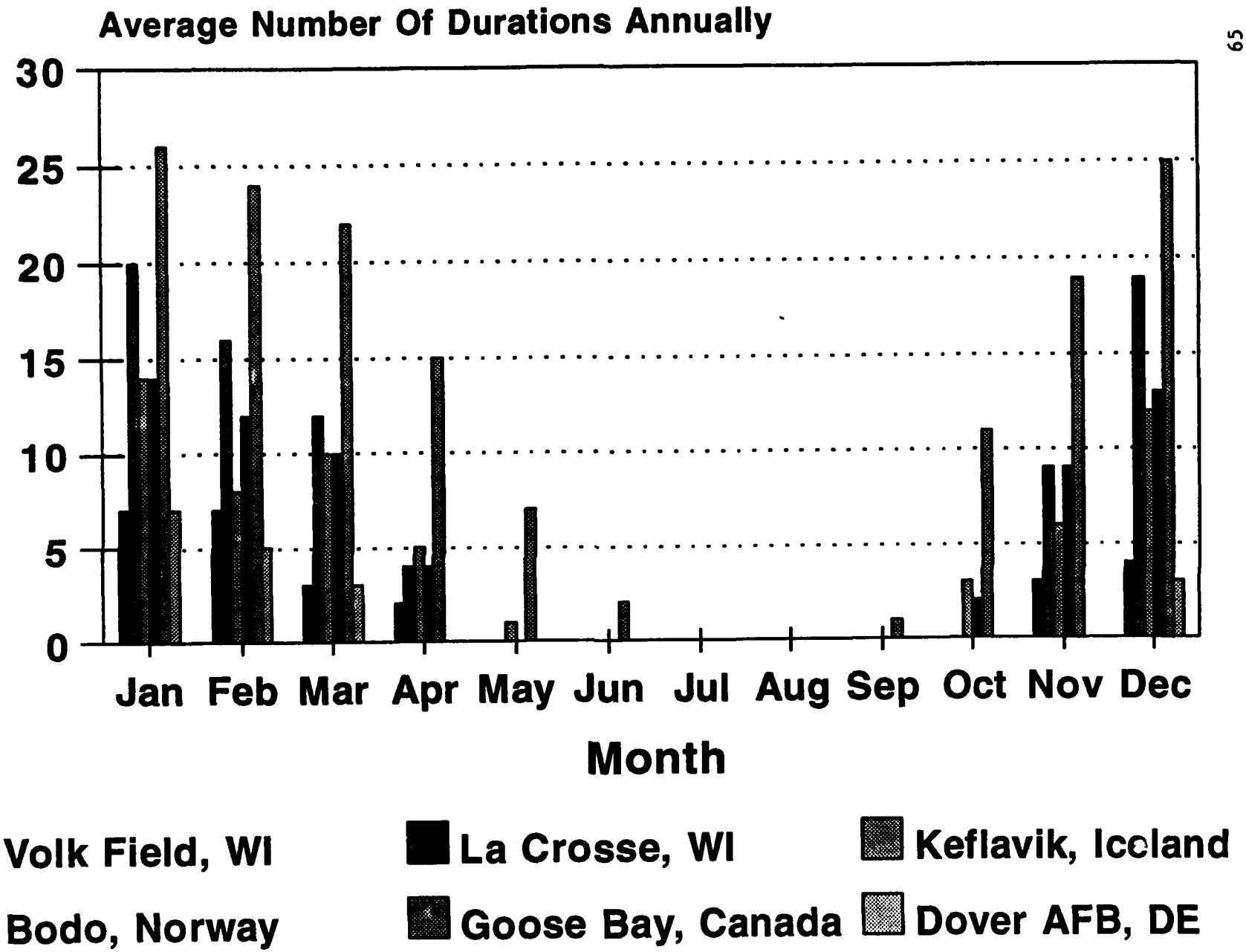

Figure B-3. Snow or Ice Pellets Not Including Freezing Precipitation

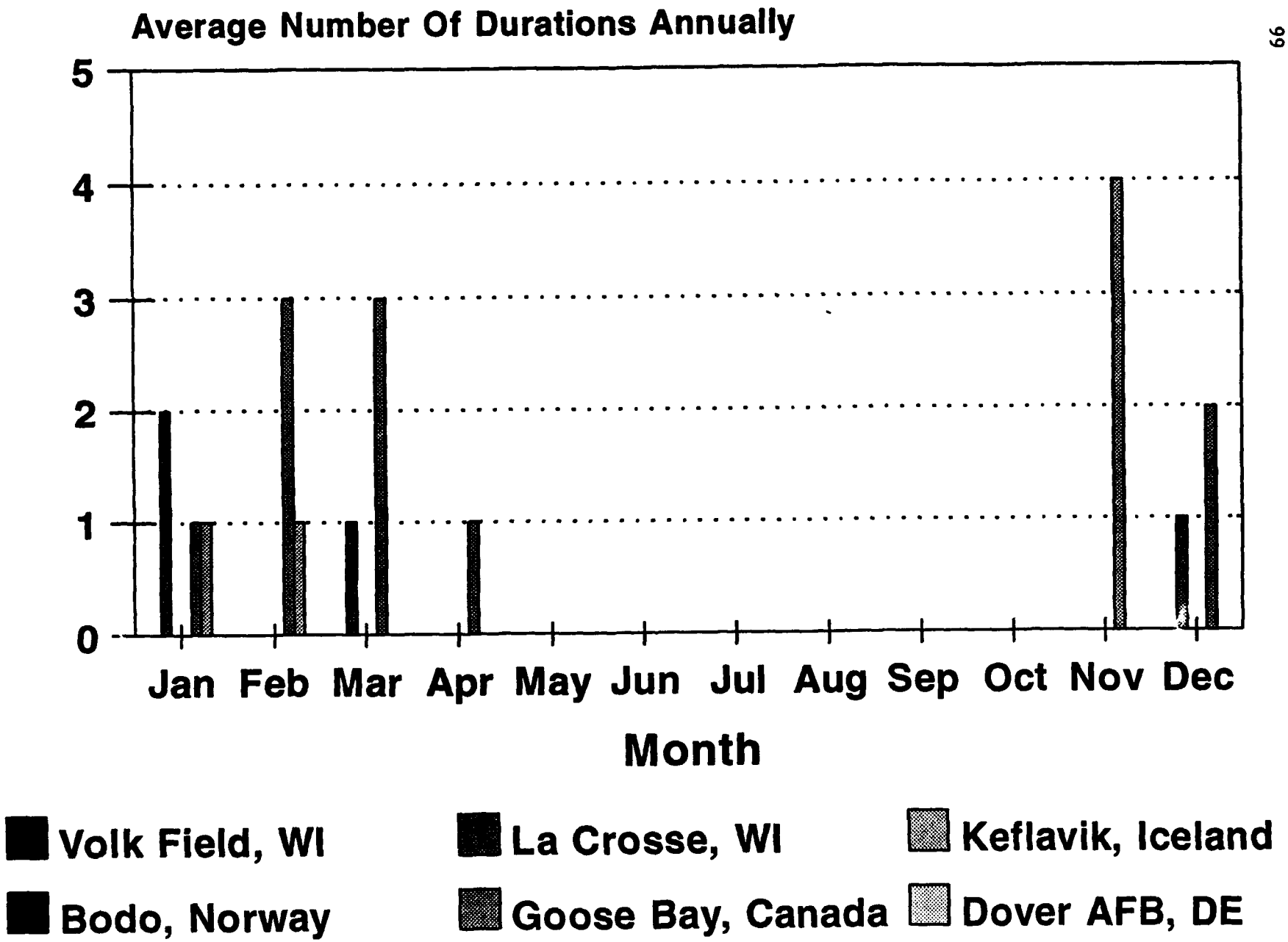

Figure B-4. Freezing Precipitation Rain or Drizzle

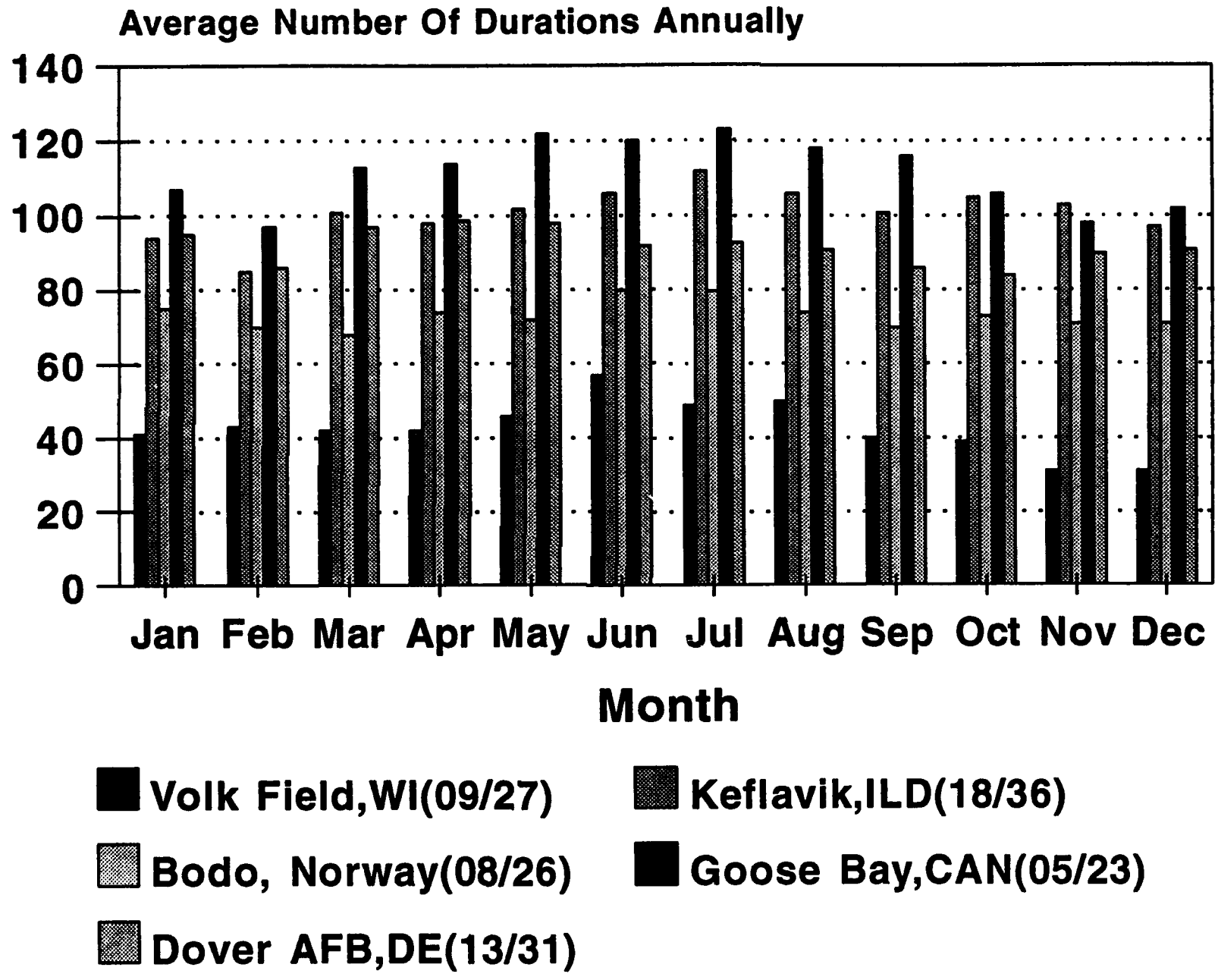

Figure B-5. Crosswinds Between 1 and 10 Knots Primary Runway

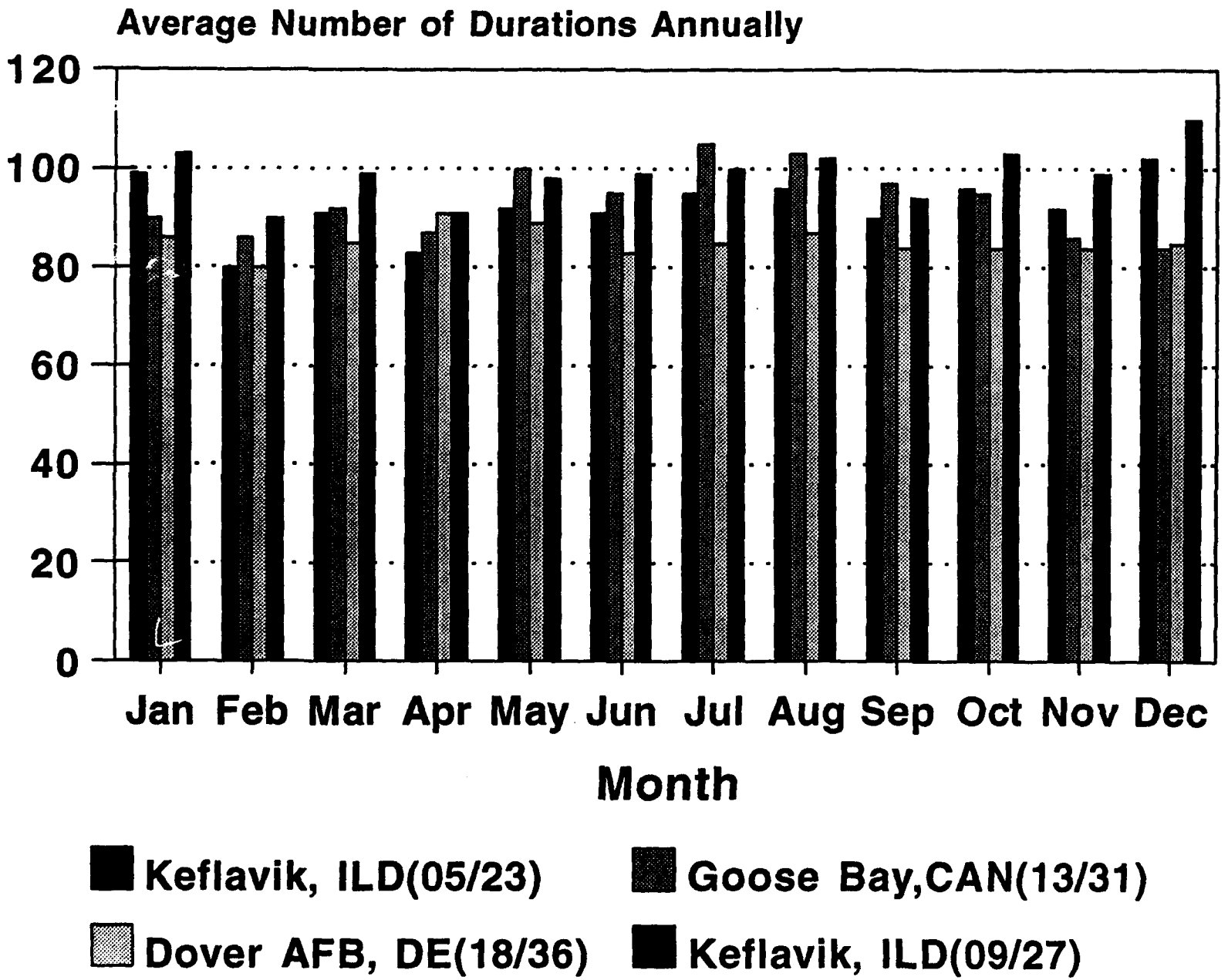

Figure B-6. Crosswinds Between 1 and 10 Knots Secondary Runways

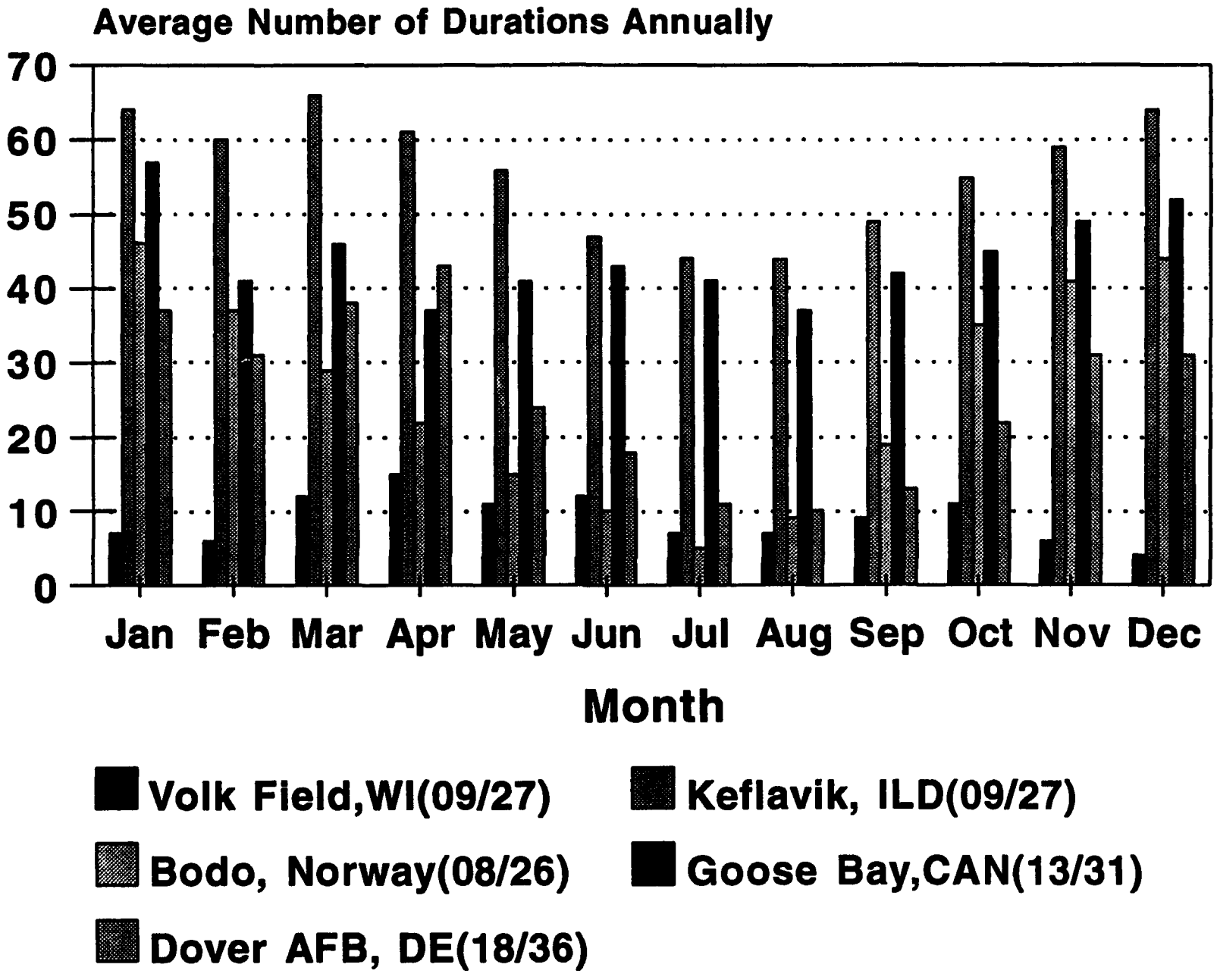

Figure B-7. Crosswinds Between 11 and 20 Knots Primary Runways

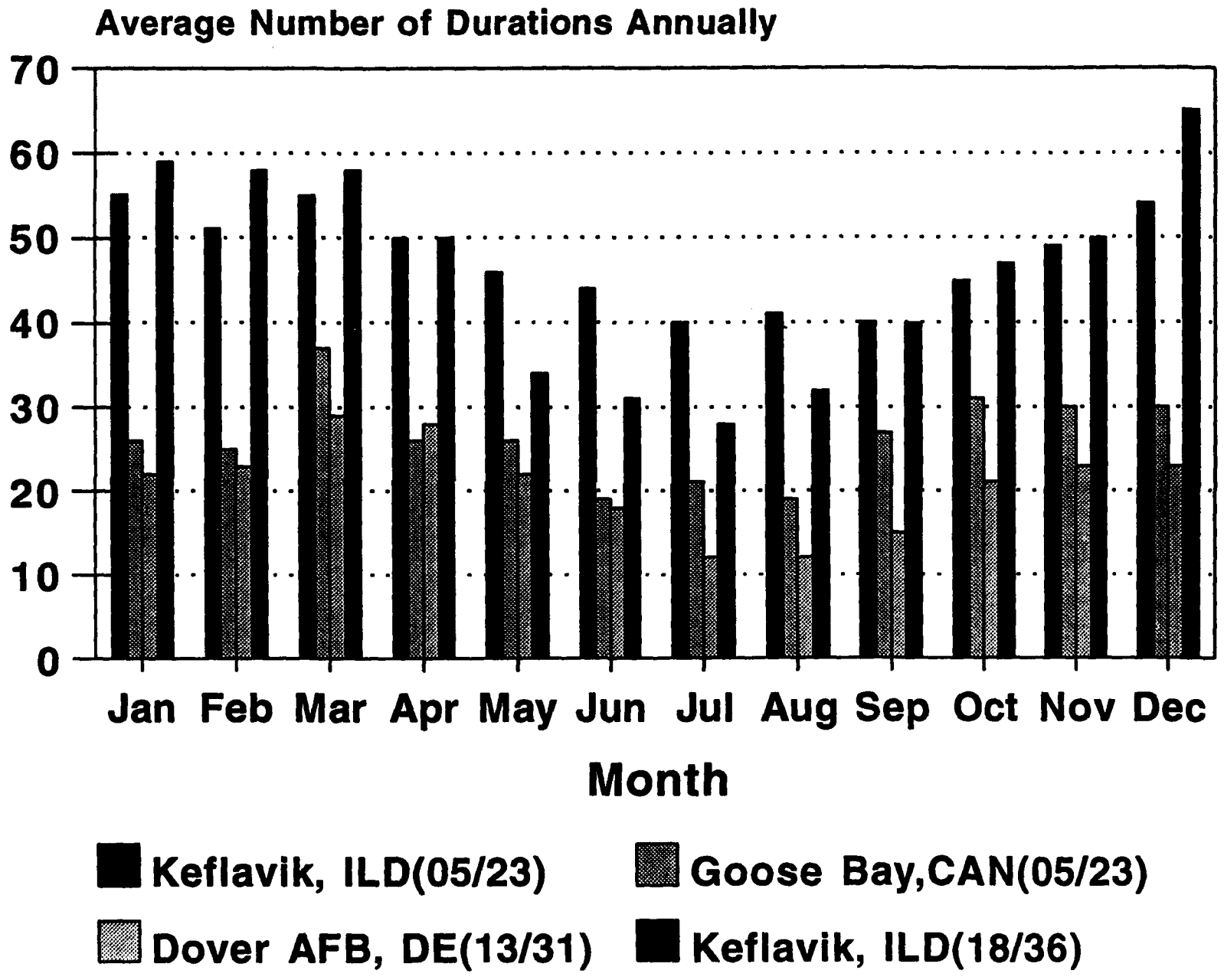

Figure B-8. Crosswinds Between 11 and 20 Knots Secondary Runways

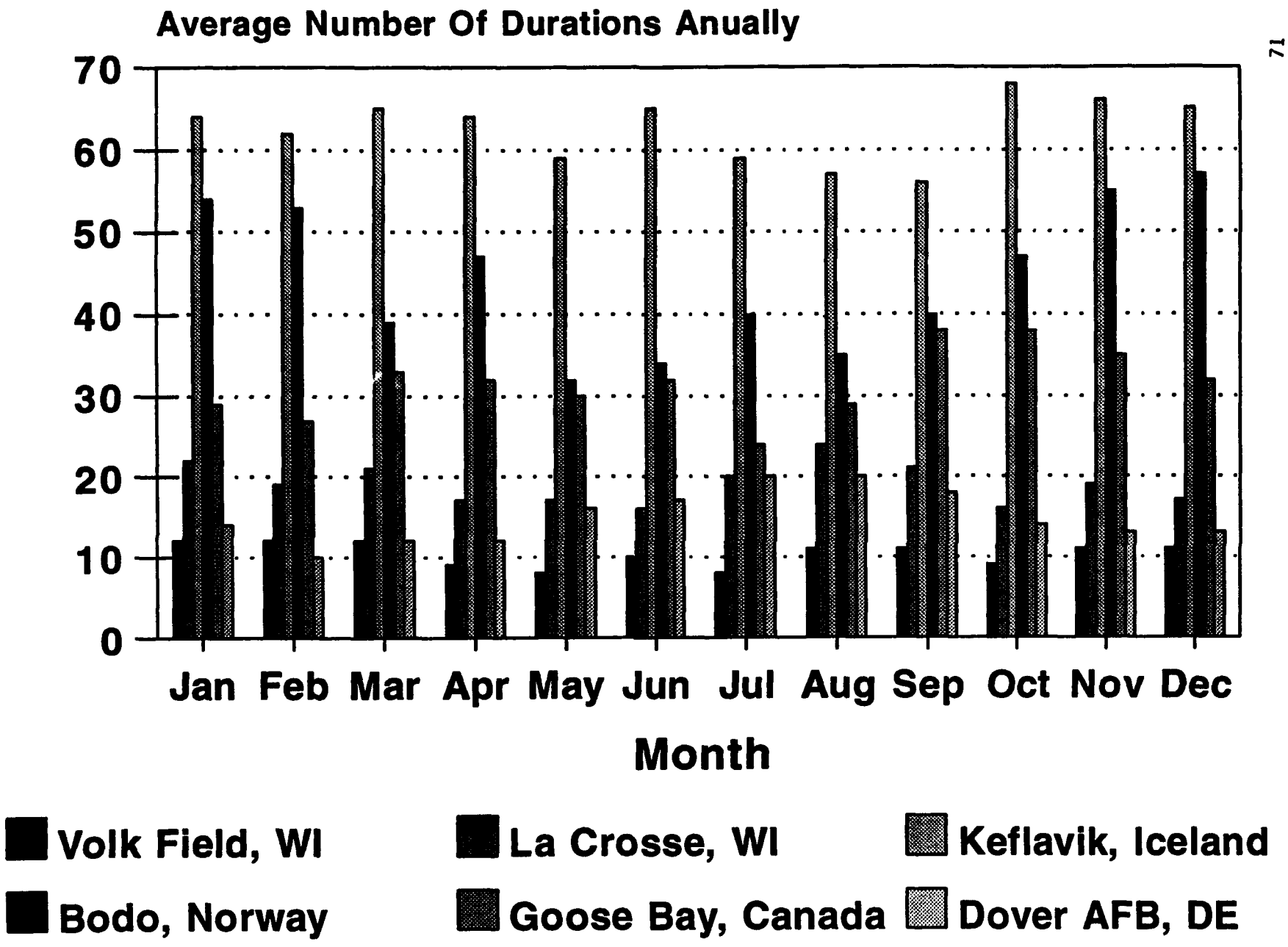

Figure B-9. Ceiling Less Than 3000 Feet or Visibility Less Than 3 Miles

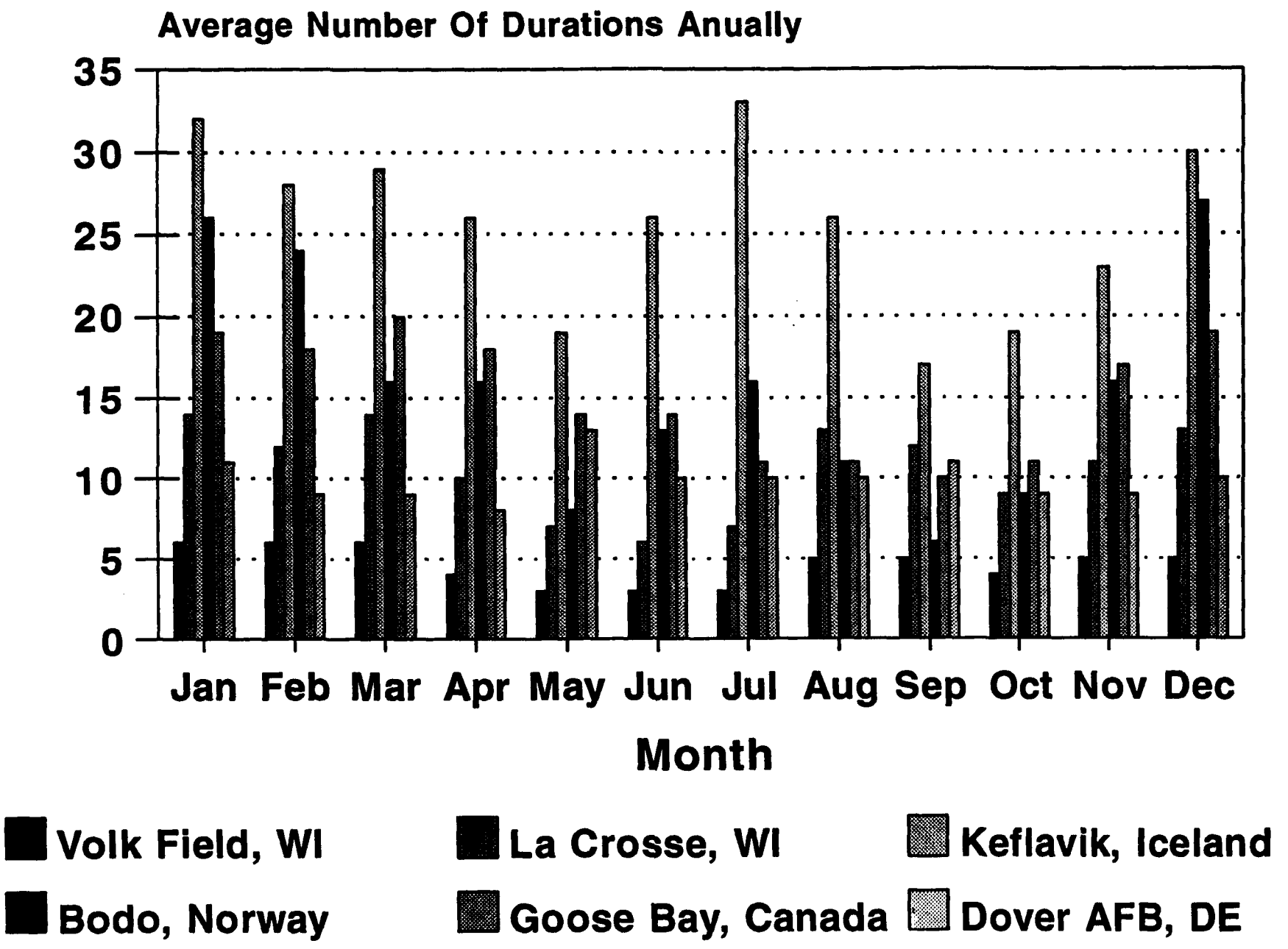

Figure B-10. Ceiling Less Than 1000 Feet or Visibility Less Than 2 Miles

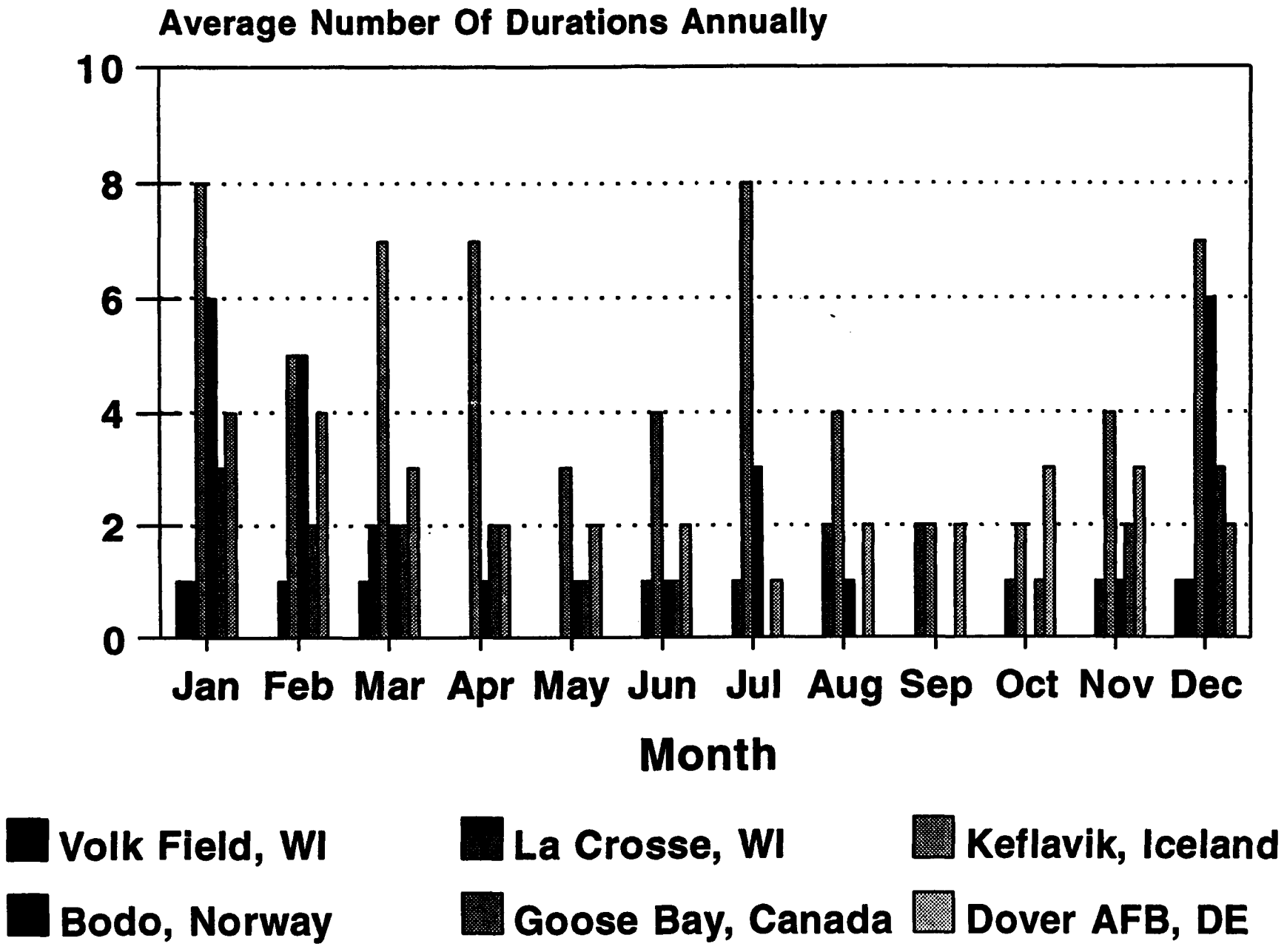

Figure B-11. Ceiling Less Than 200 Feet or Visibility Less Than 1/2 Mile

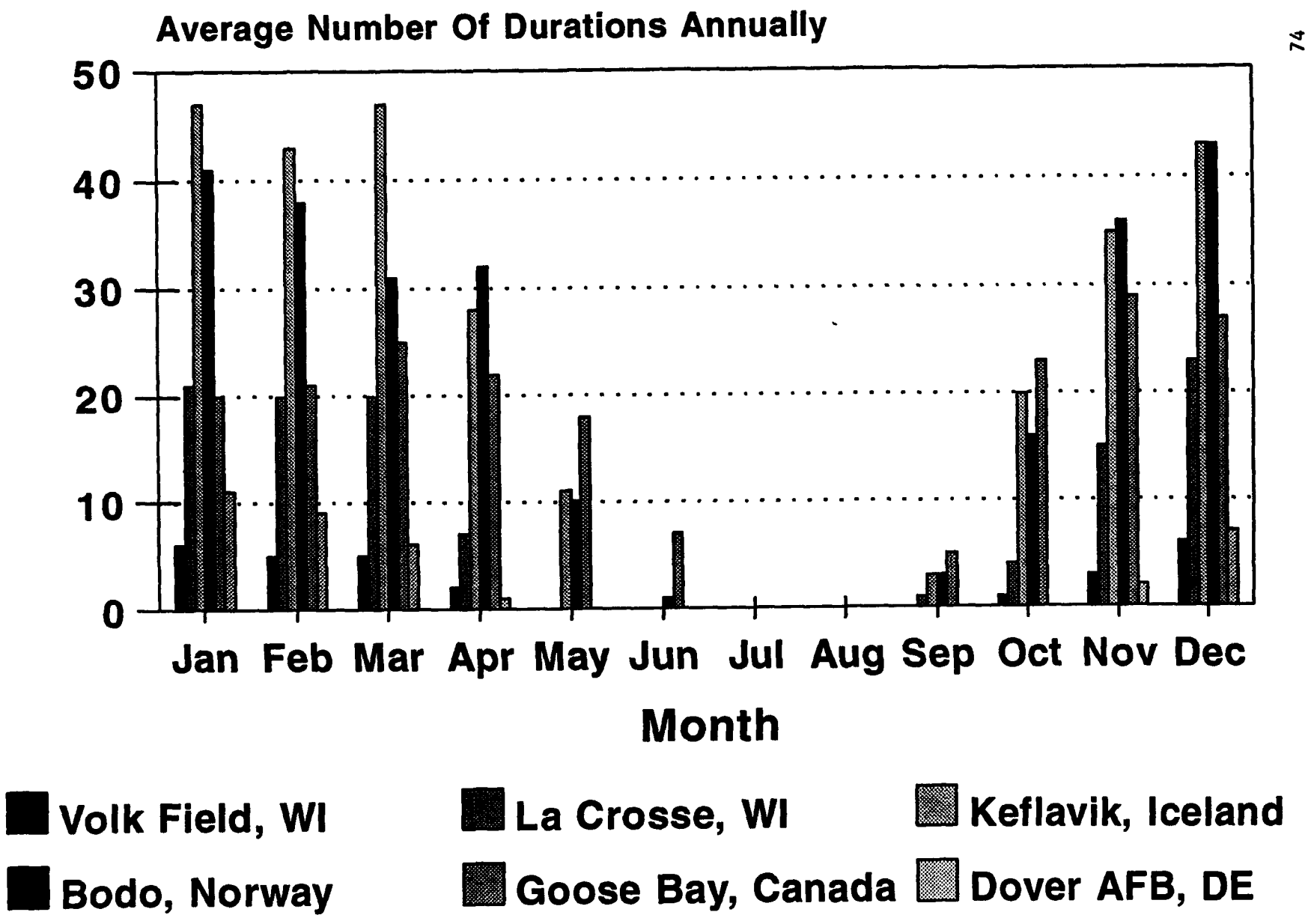

Figure B-12. Temperature Less Than 40 F, Relative Humidity Greater Than or Equal to 80 Percent, and Precipitation

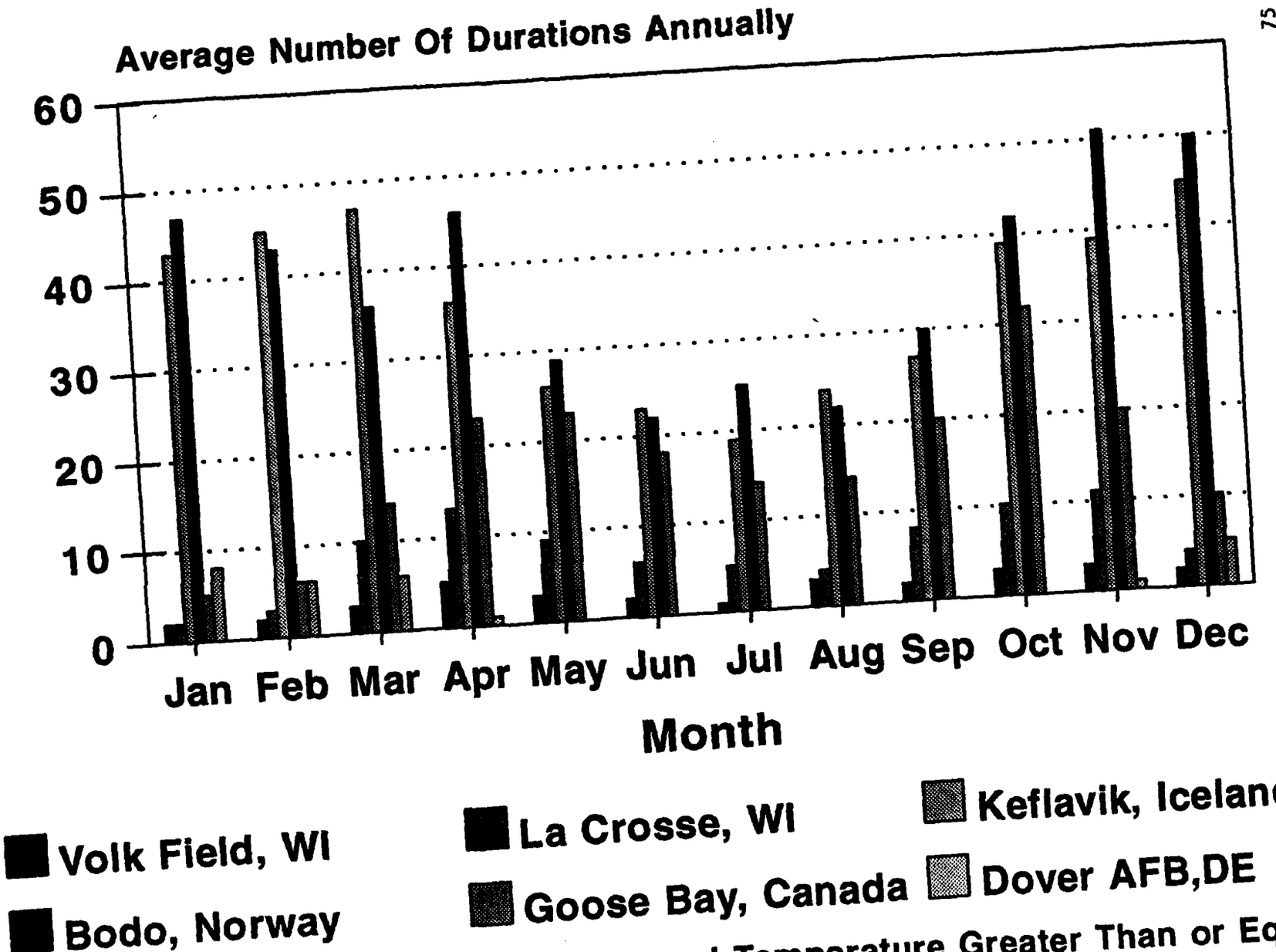

Figure B-13. Precipitation Not Freezing and Temperature Greater Than or Equal to 20 F but Less Than or Equal to 40 F

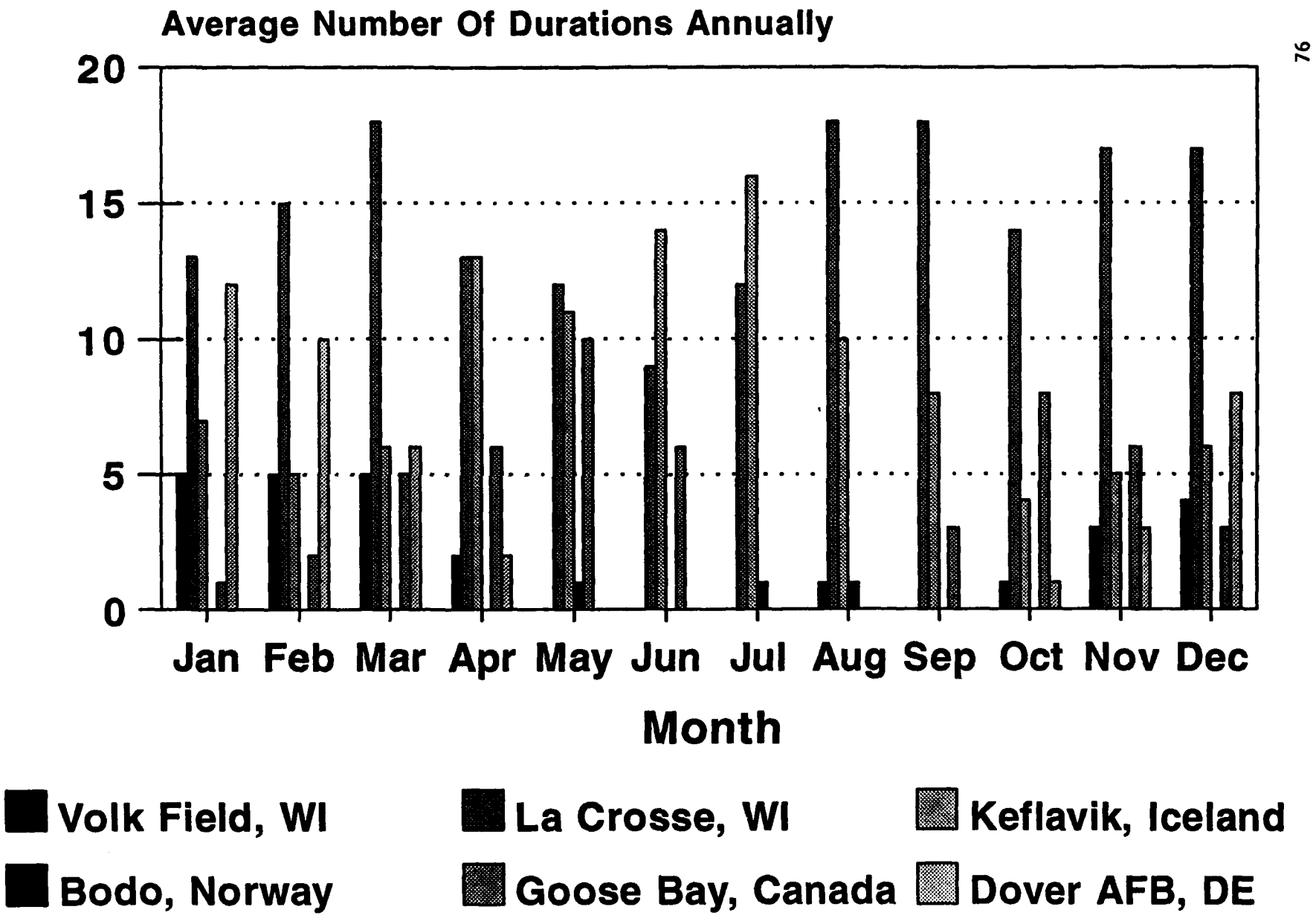

Figure B-14. Fog or Mist and Temperature Greater Than or Equal to 20 F but Less Than or Equal to 40 F

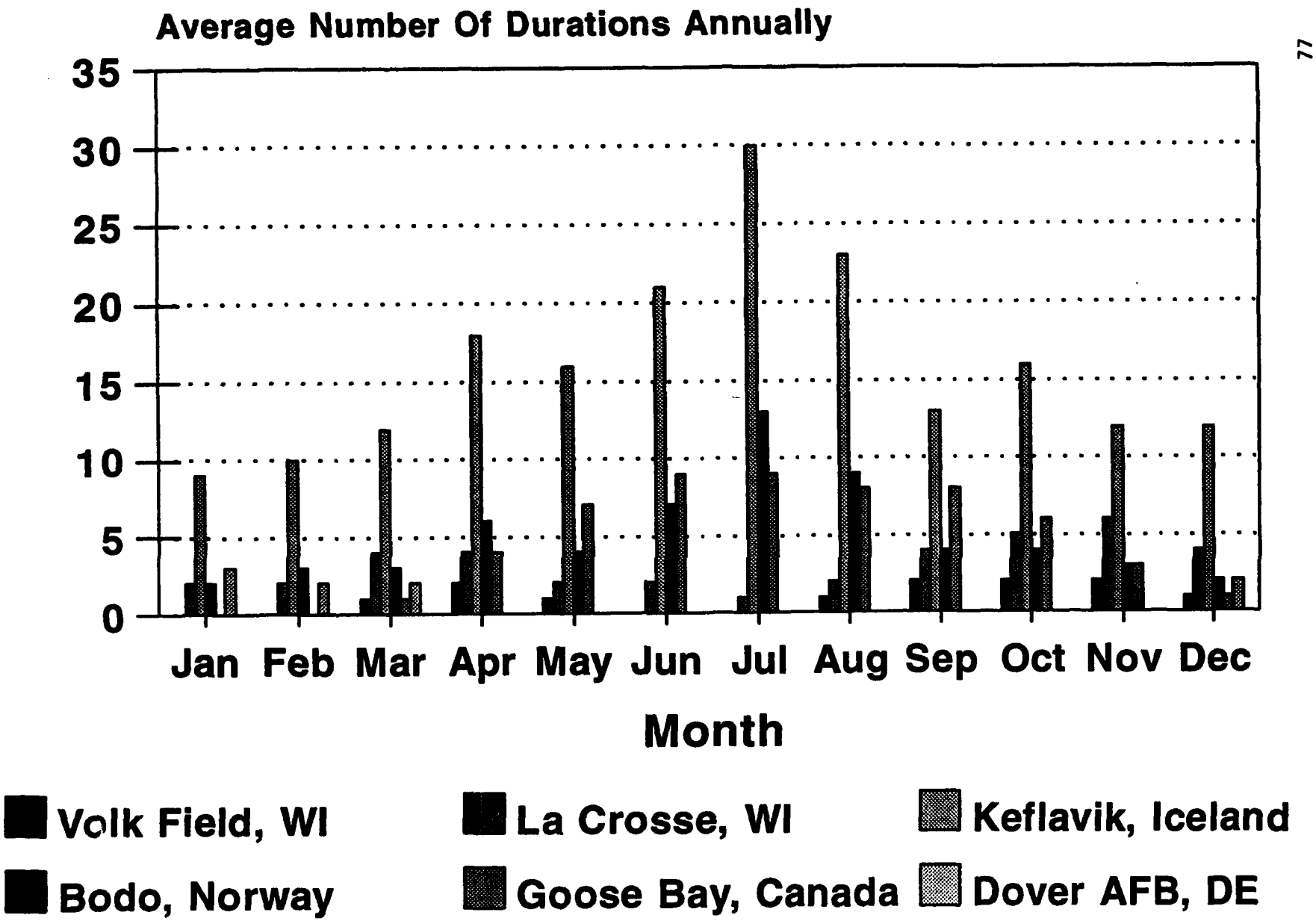

Figure B-15. Drizzle and Temperature Greater Than or Equal to 20 F but Less Than or Equal to 40 F

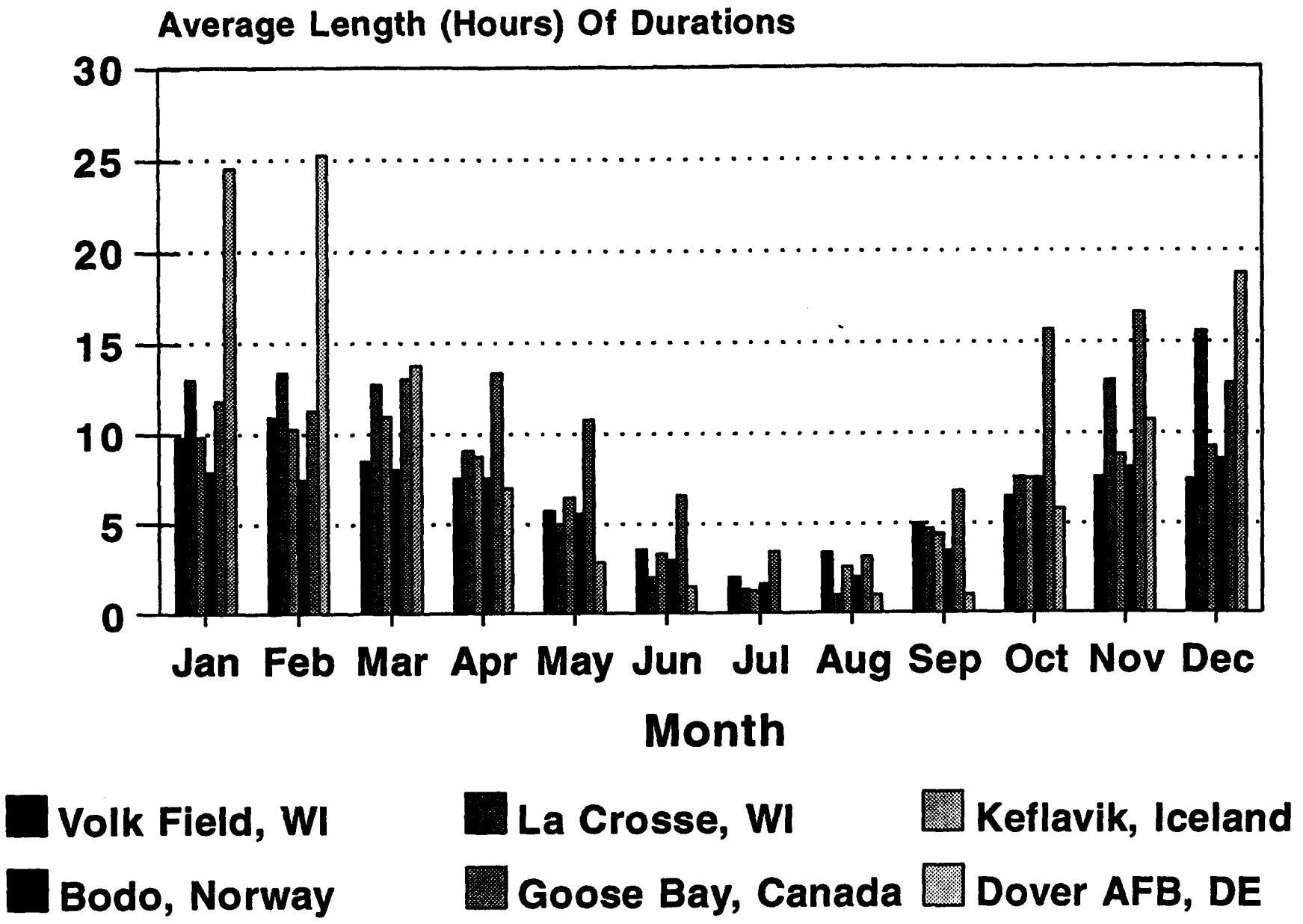

Figure B-16. Temperature Greater Than or Equal to 20 F and Less Than or Equal to 40 F

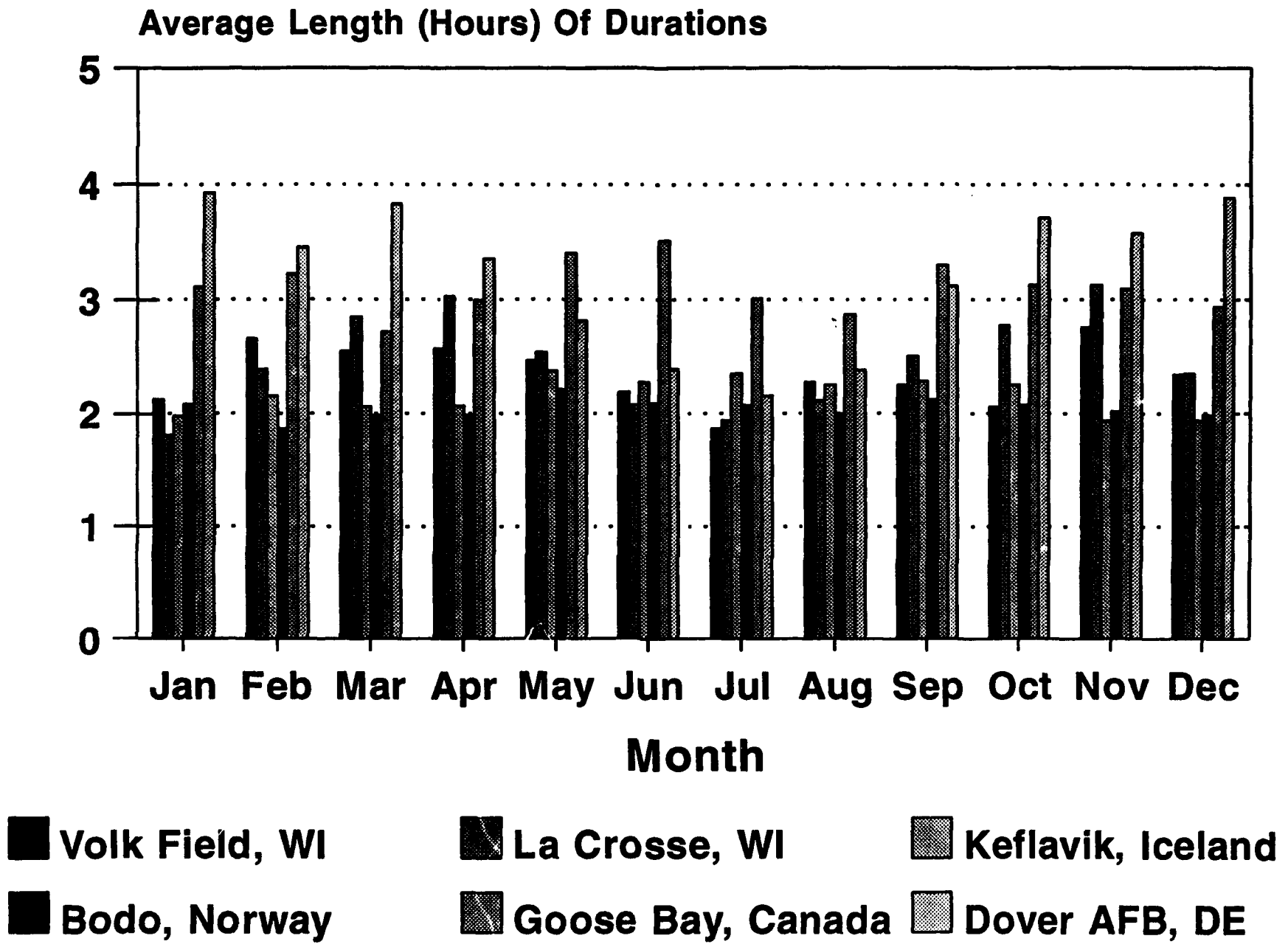

Figure B-17. Non-Freezing Precipitation

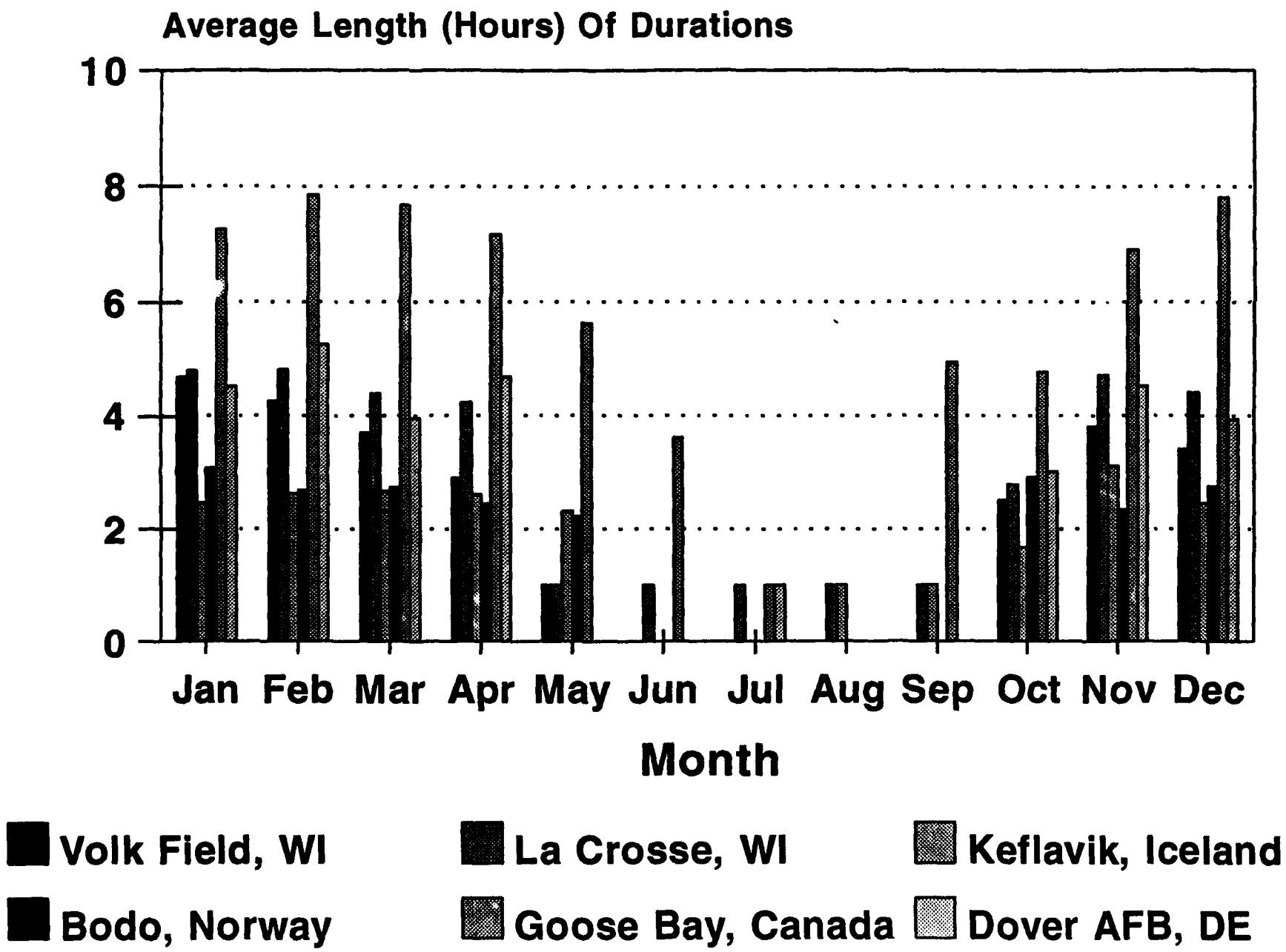

Figure B-18. Snow or Ice Pellets Not Including Freezing Precipitation

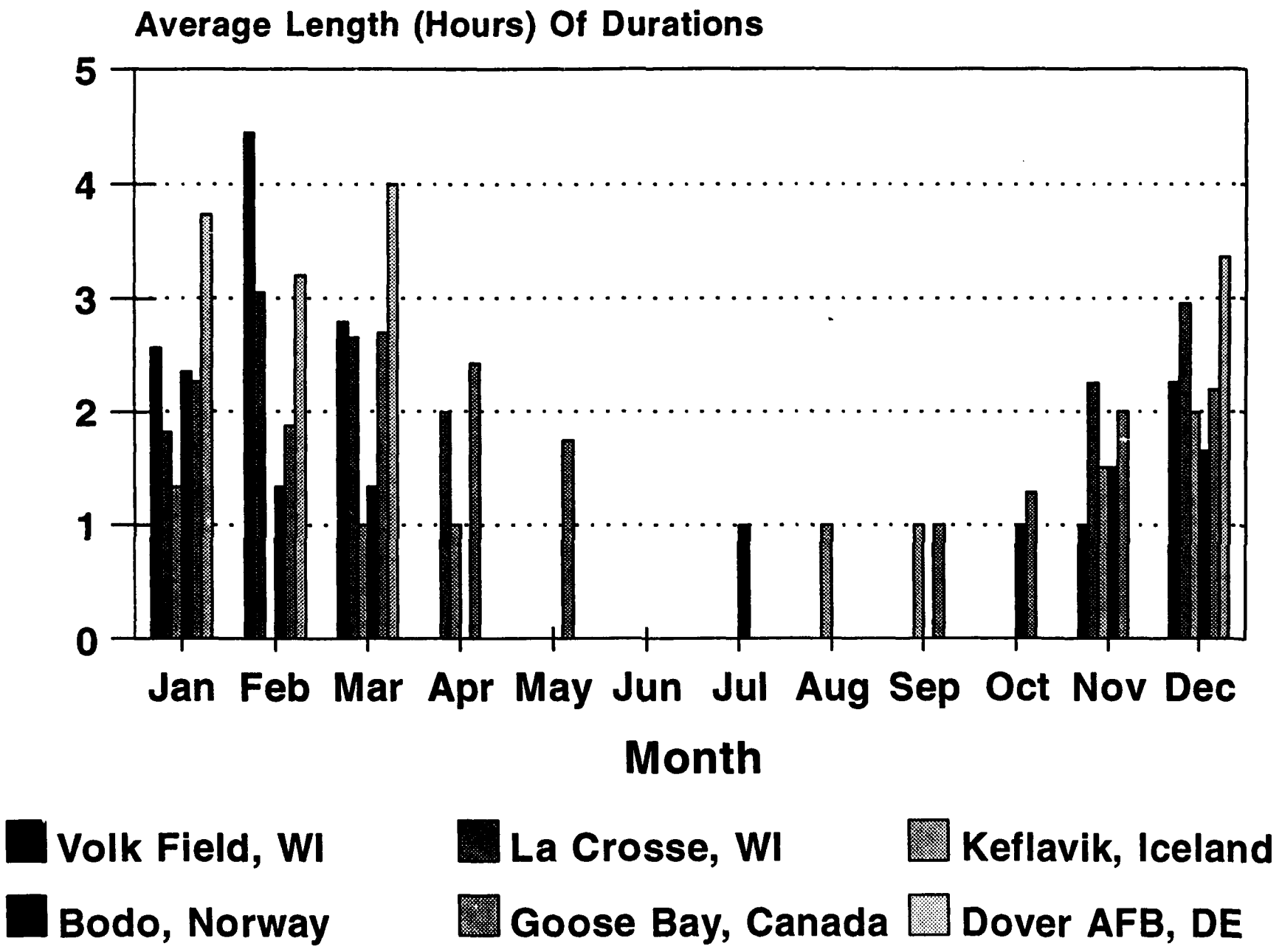

Figure B-19. Freezing Precipitation Rain or Drizzle

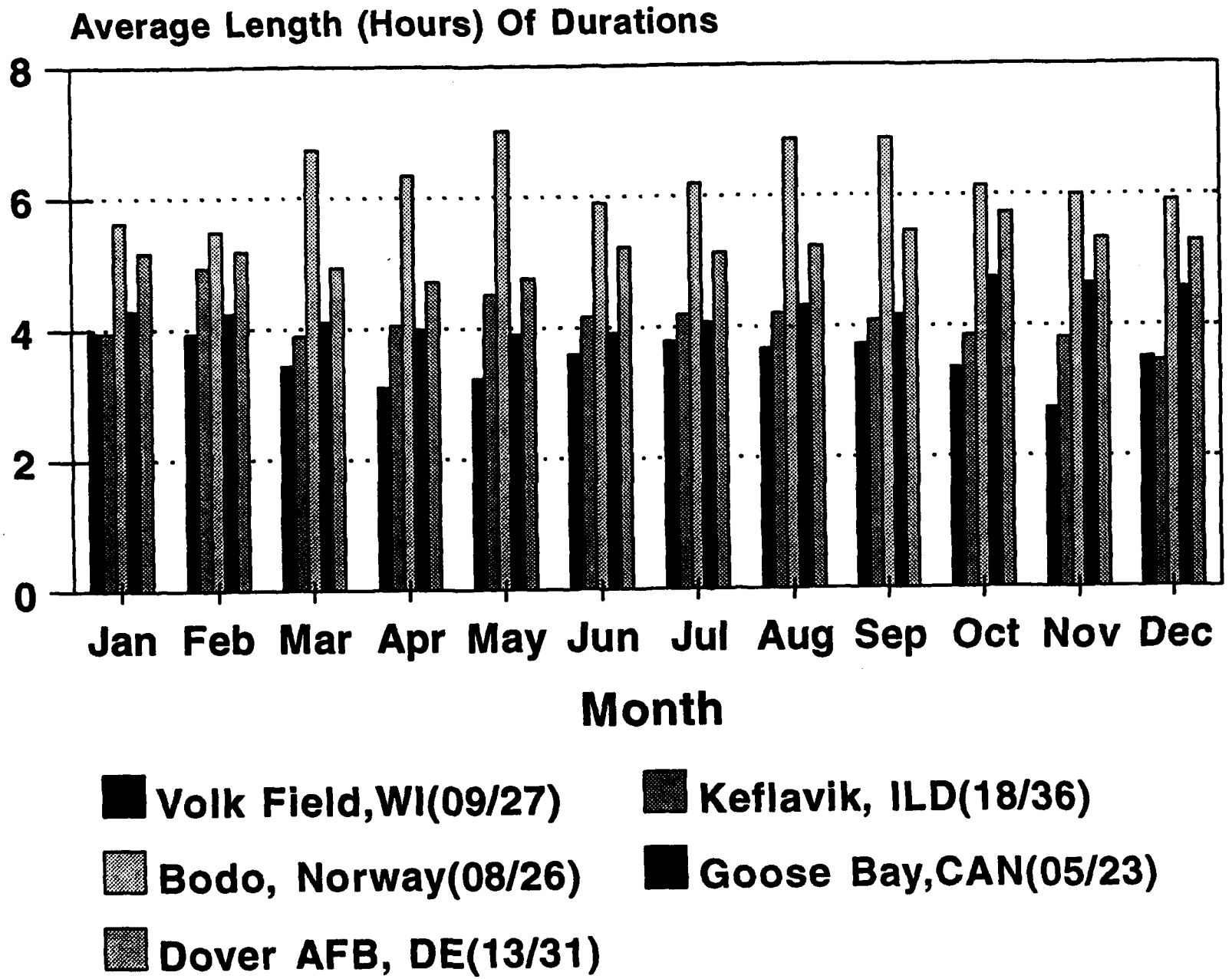

Figure B-20. Crosswinds Between 1 and 10 Knots Primary Runways

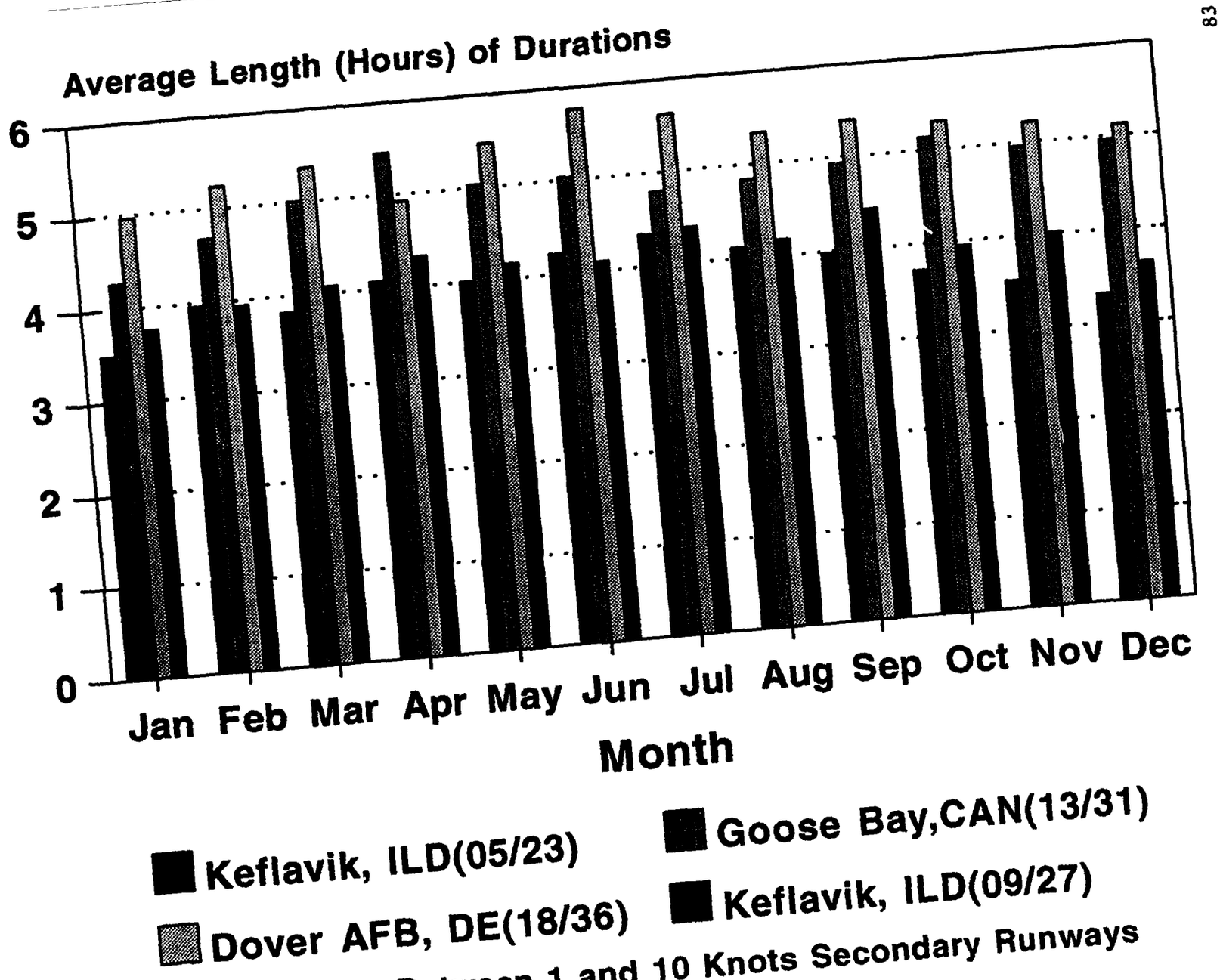

Figure B-21. Crosswinds Between 1 and 10 Knots Secondary Runways

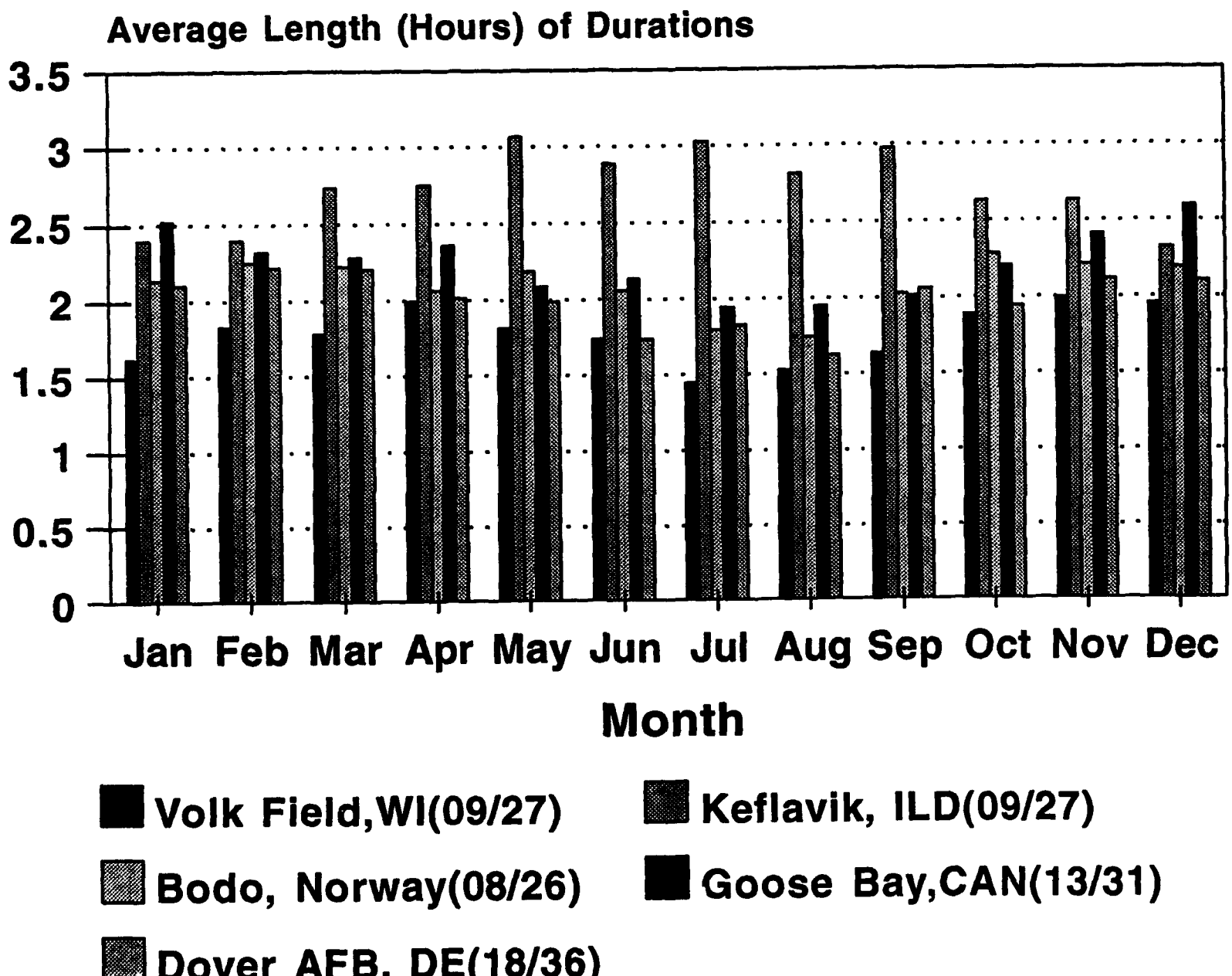

Figure B-22. Crosswinds Between 11 and 20 Knots Primary Runways

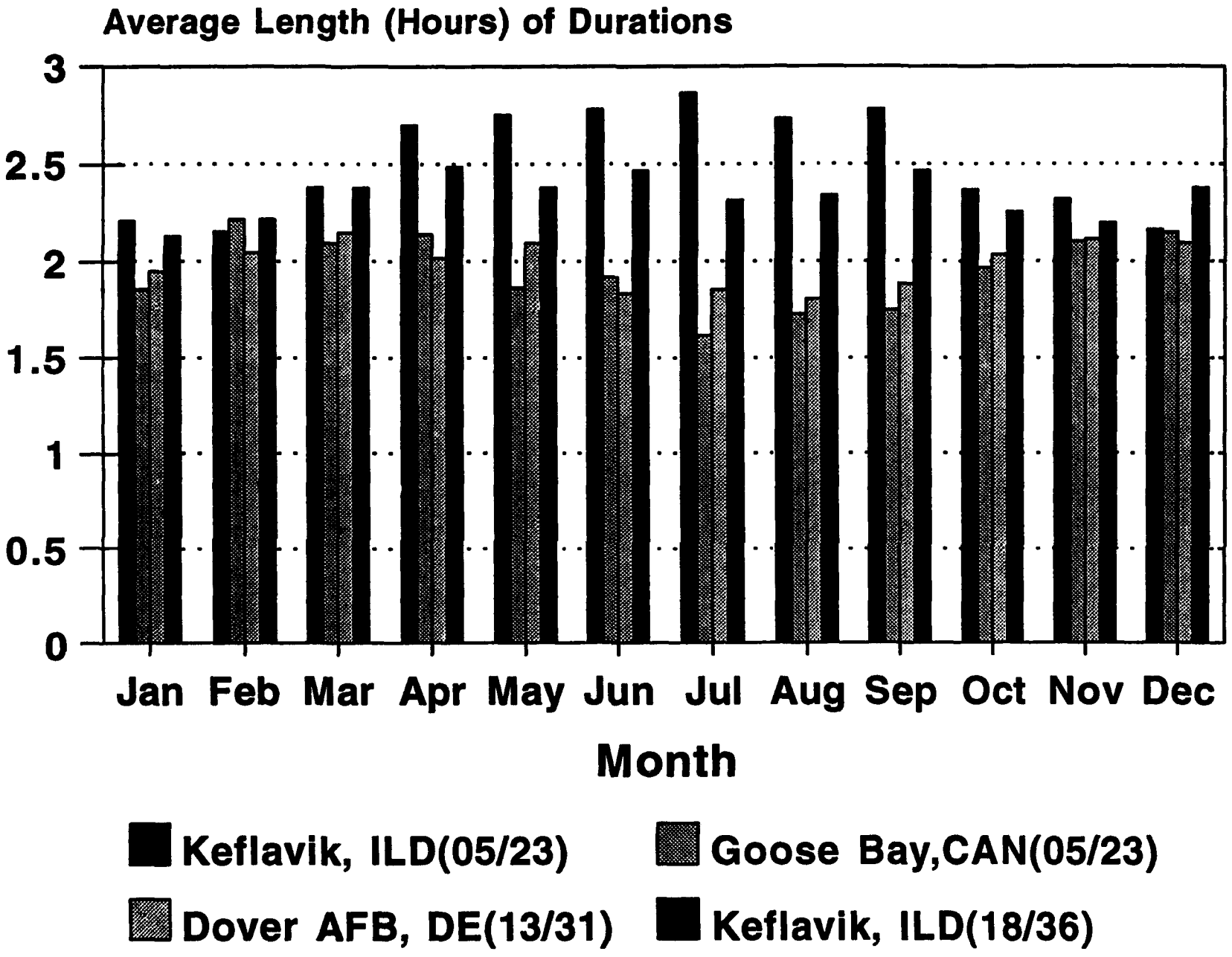

Figure B-23. Crosswinds Between 11 and 20 Knots Secondary Runways

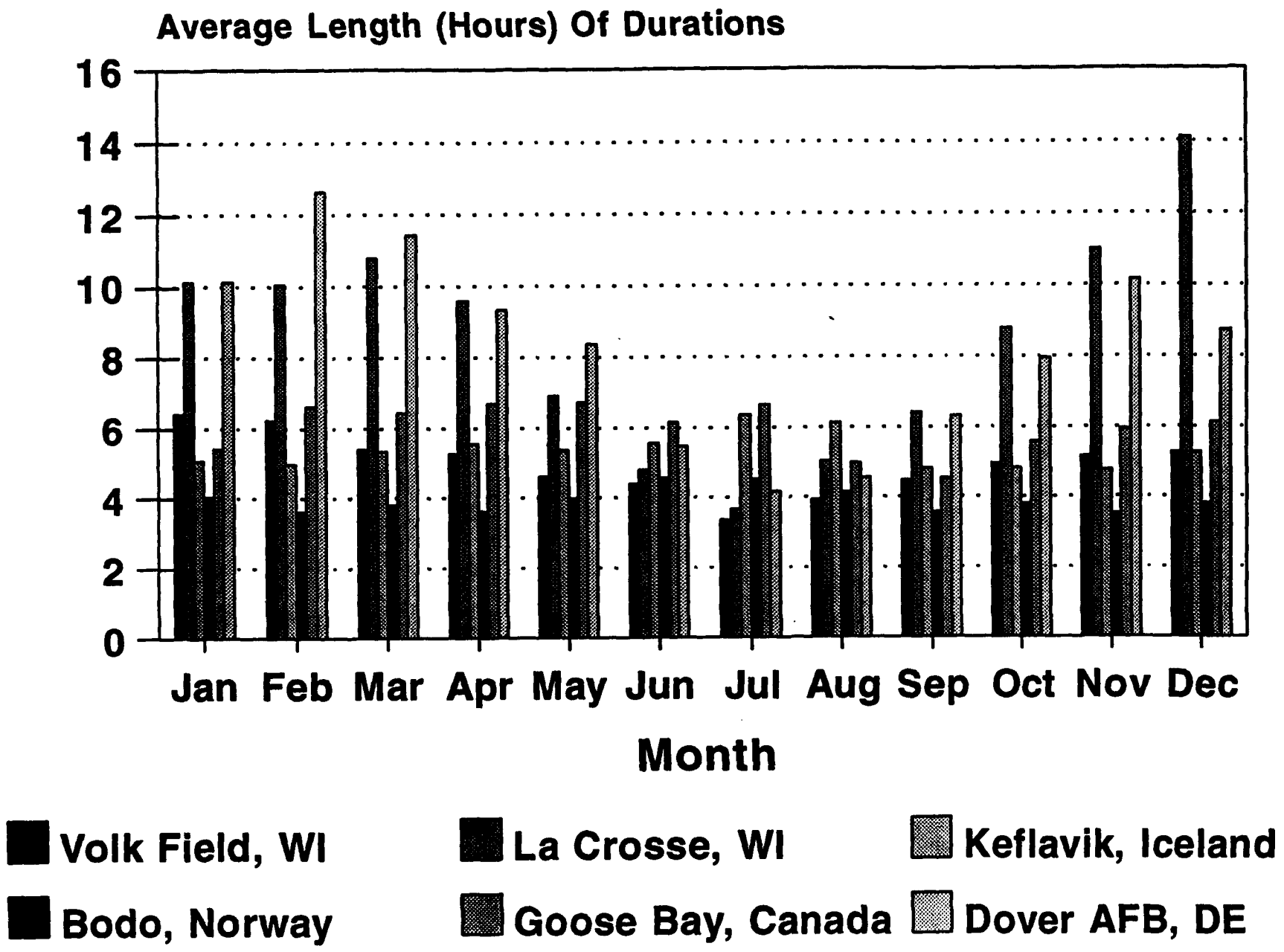

Figure B-24. Ceiling Less Than 3000 Feet or Visibility Less Than 3 Miles

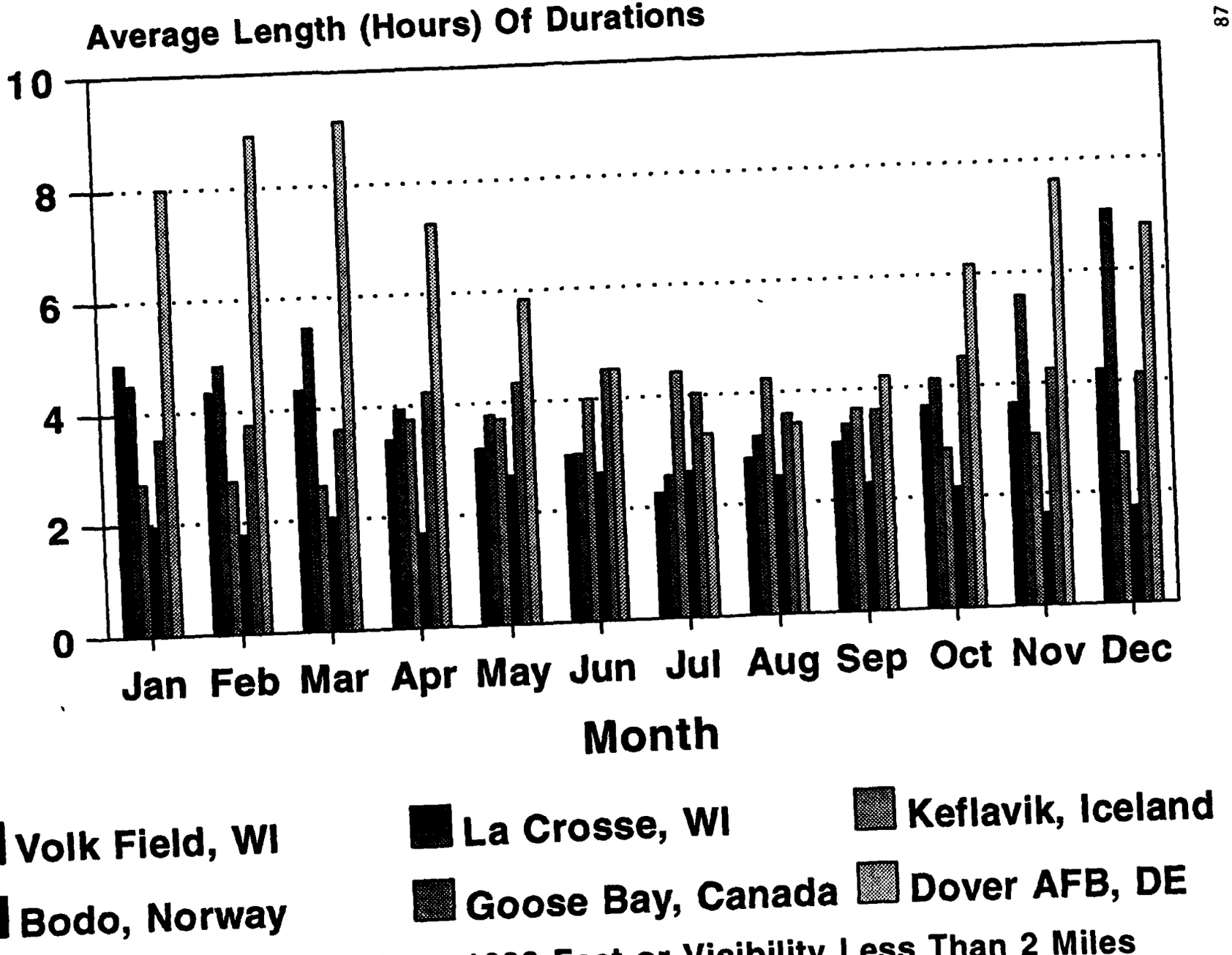

Figure B-25. Ceiling Less Than 1000 Feet or Visibility Less Than 2 Miles

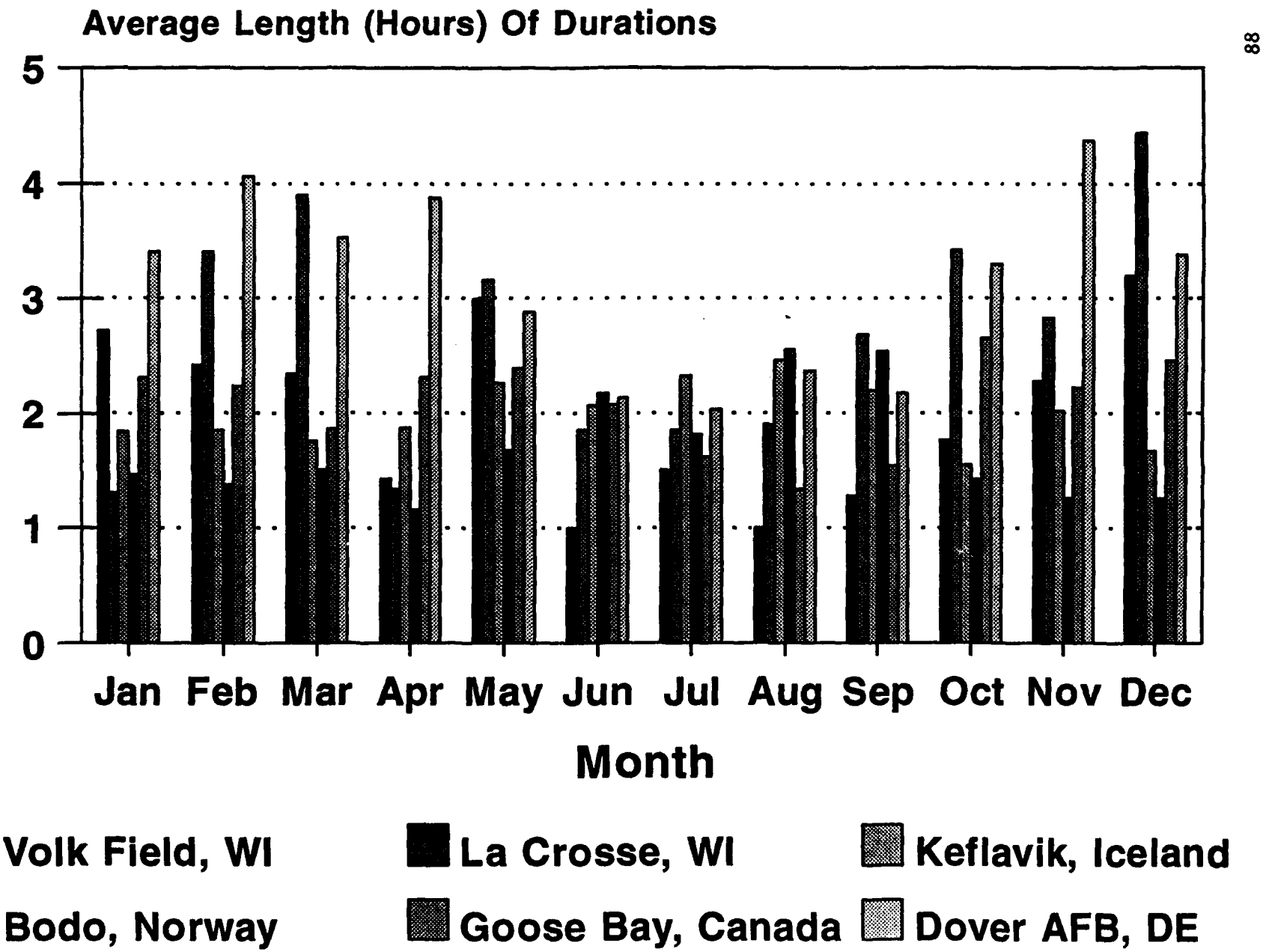

Figure B-26. Ceiling Less Than 200 Feet or Visibility Less Than 1/2 Mile

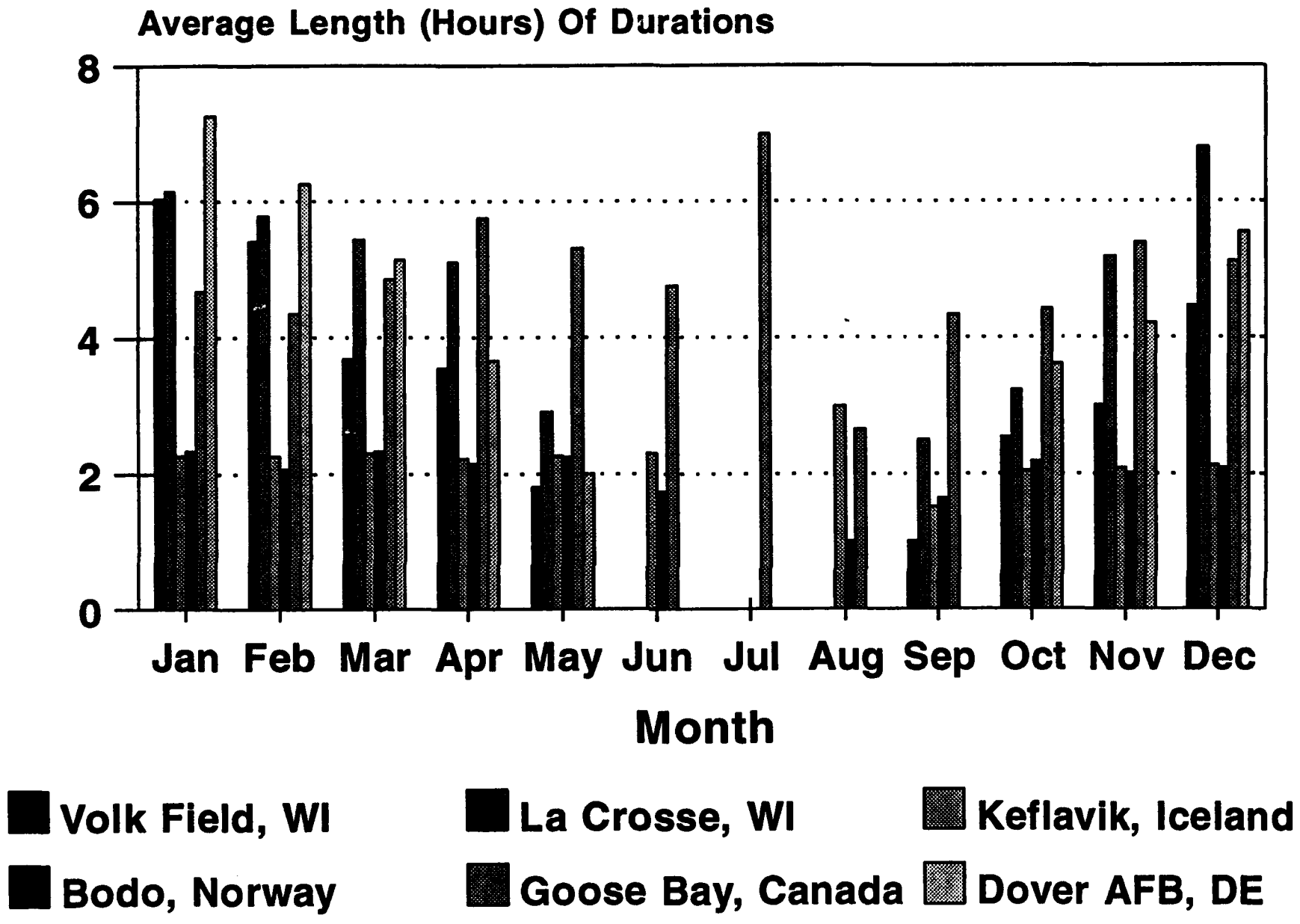

Figure B-27. Temperature Less Than or Equal to 40 F, Relative Humidity Greater Than or Equal to 80 Percent, and Precipitation

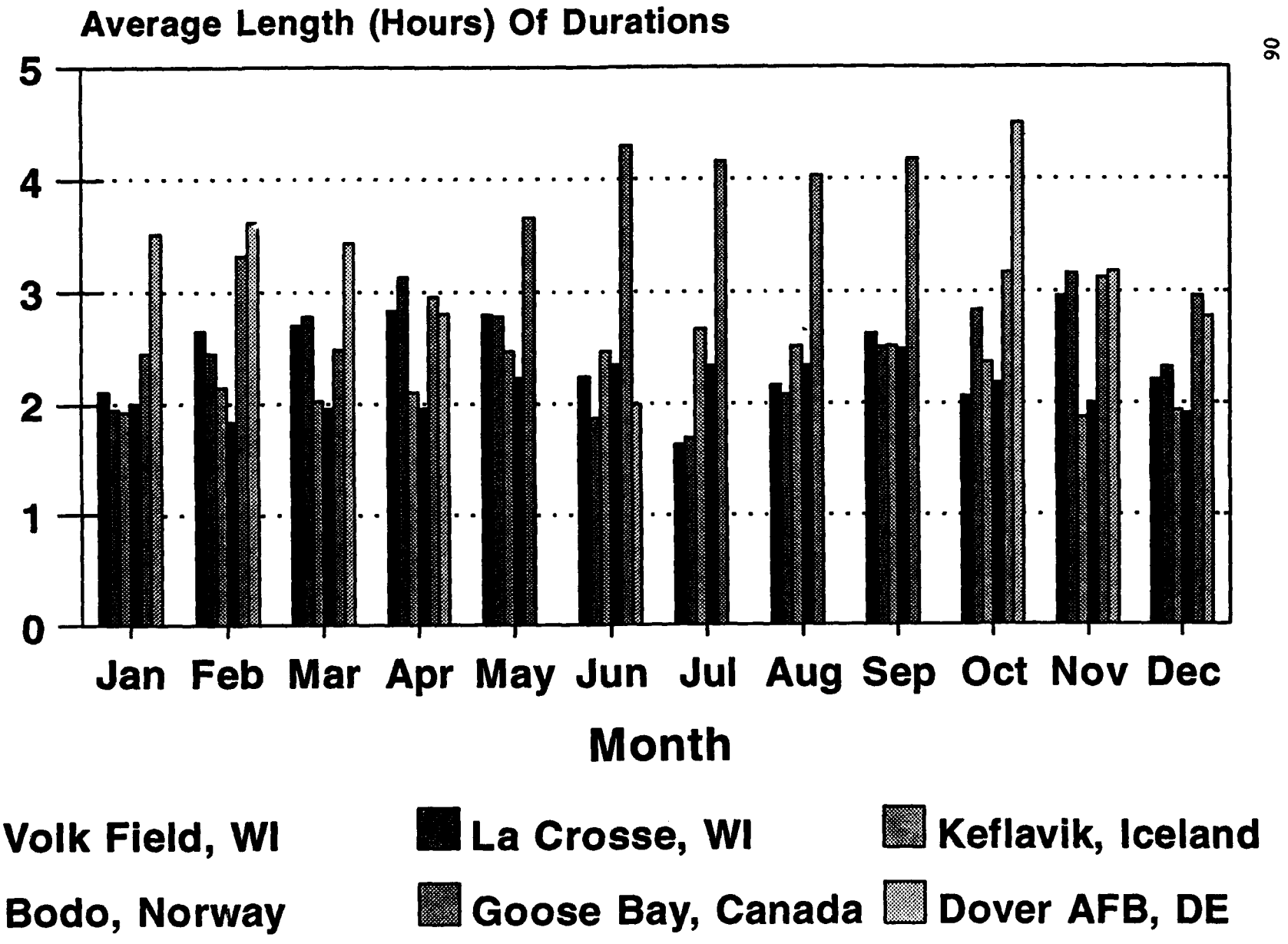

Figure B-28. Precipitation Not Freezing and Temperature Greater Than or Equal to 20 F but Less Than or Equal to 40 F

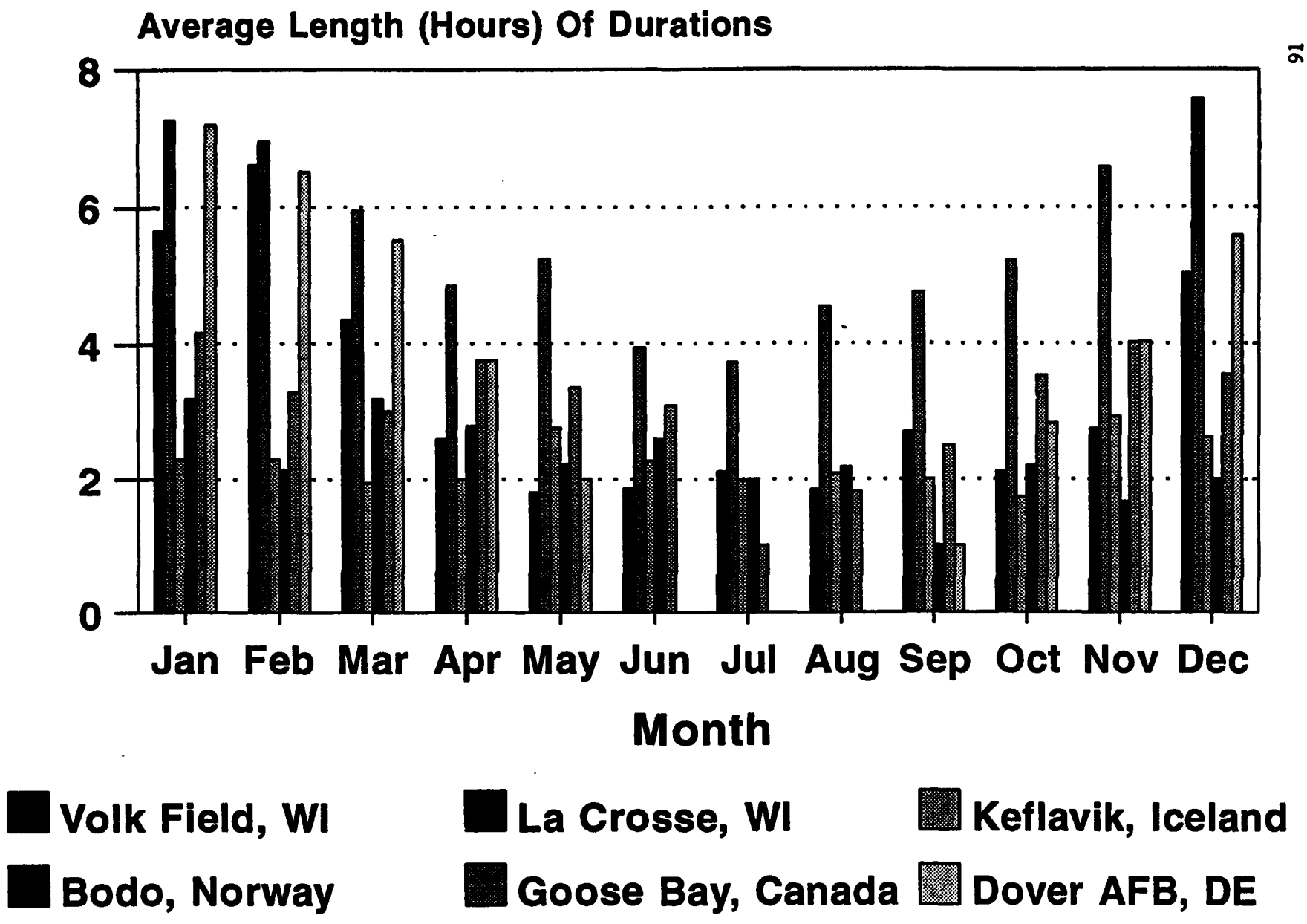

Figure B-29. Fog or Mist and Temperature Greater Than or Equal to 20 F but Less Than or Equal to 40 F

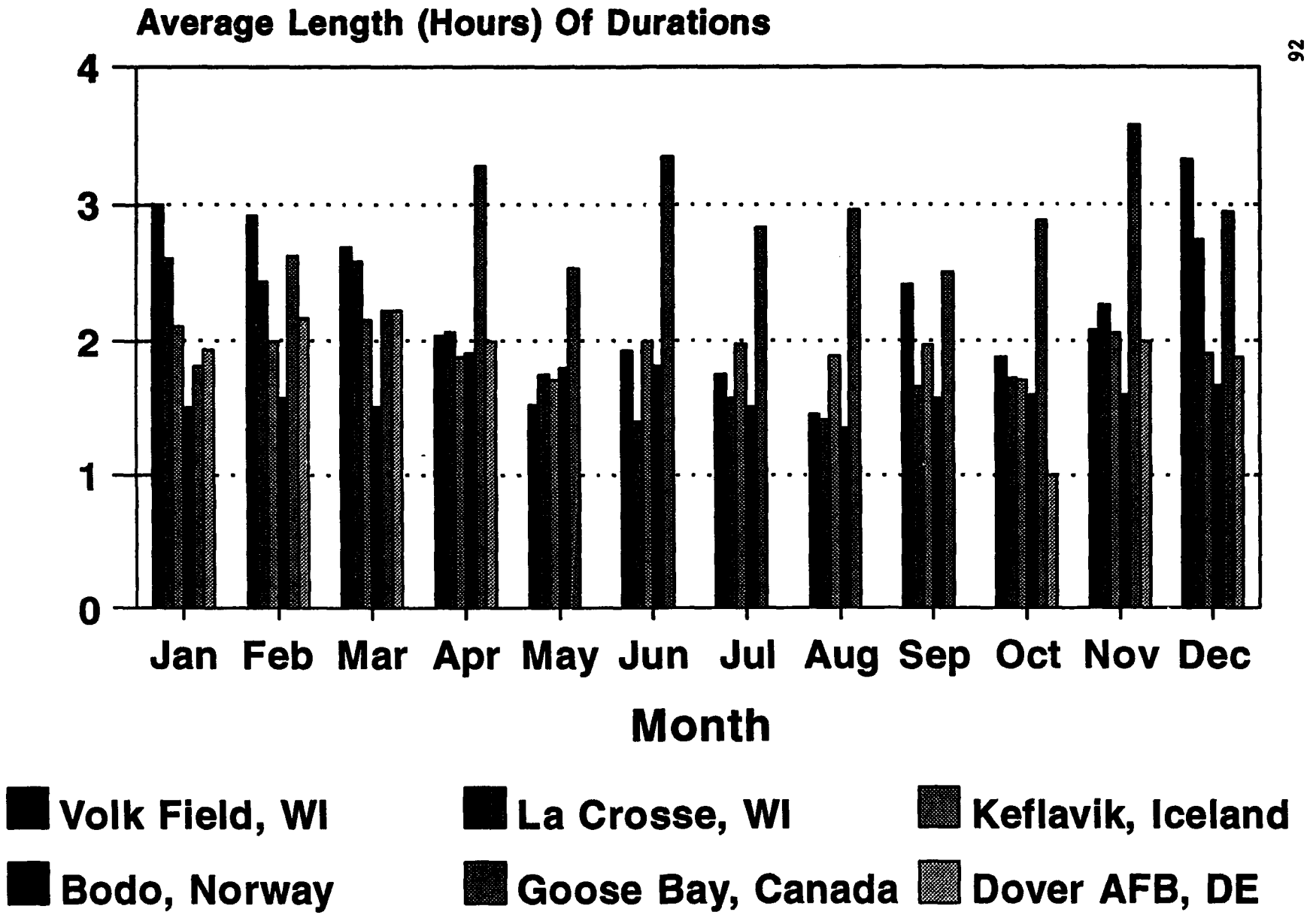

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Figure B-30. Drizzle and Temperature Greater Than or Equal to 20 F but Less Than or Equal to 40 F