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MODEL OUTPUT STATISTICS (MOS) FORECAST GUIDANCE FOR U.S. AIR FORCE LOCATIONS IN ALASKA

Jeanette M. Baker, Capt. USAF

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1. INTRODUCTION

Beginning on 15 February 1984, Model Output Statistics (MOS) forecasts have been available in FOAK teletype bulletins for 13 military locations in Alaska. The bulletins contain the following weather guidance: probability of precipitation (PoP), probability of frozen precipitation (PoF), surface temperature (TEMP), surface wind (WIND), cloud amount (CLD), visibility (VIS), obstructions to vision (OBVIS), and ceiling height (CIG). MOS forecasts of these elements are available twice daily in the FOAK bulletins which are routed through Carswell AFB to military locations in Alaska. Personnel from the Techniques Development Laboratory in conjunction with the resident U.S. Air Force Liaison developed the FOAK series automated weather guidance bulletin. The new guidance uses output from the Limited-area Fine Mesh (LFM) model (Newell and Deaven, 1981; Gerrity, 1977) to produce the MOS forecasts. Forecasts for some of these elements were previously included in the terminal aerodrome forecast (TAF) bulletins using the station oriented forecast matrix (SOFTRIX) software. The TAF bulletins for Alaska were replaced with the FOAK series to provide more complete forecast data for the military sites in Alaska.

The forecasts produced for the new FOAK bulletins are generated twice daily during both the 0000 and 1200 GMT forecast cycles for the stations listed in Table 1. The bulletins are available at about 0330 and 1600 GMT to U.S. Air Force forecasters through the Air Force Global Weather Central message switching center at Carswell AFB, Texas.

2. METHOD

All the prediction equations are based on the MOS Approach (Glahn and Lowry, 1972) whereby statistical relationships are determined between observed occurrences of weather elements (predictands) and forecast output from one or more numerical prediction models (predictors). A forward selection screening procedure was used to derive multiple linear regression equations.

The predictors, which consisted mainly of output from the LFM model, were space-smoothed over five or nine model grid points in order to reduce the amount of small-scale noise inherent in the numerical output. Both the amount of smoothing and the number of fields smoothed increased as the length of the model forecast projection increased. All of the fields were interpolated from grid points to the appropriate station locations.

In addition, surface weather observations taken 3 hours after each forecast cycle (0000 and 1200 GMT) and geo-climatic variables were used as predictors. For each weather element, "primary" and "backup" equations were developed for specific projections. The primary equations include observed weather elements as predictors, while the backup equations do not. In day-to-day operations, when necessary observed predictors from the surface observation are not available for any element at a particular station, the backup equation is used to generate the forecast.

All the developmental data sets except those for the PoF equations were stratified into the four seasons of fall (September-October), winter (November-March), spring (April-May), and summer (June-August). The developmental sample for the fall season consisted of approximately five seasons of data from 1977 to 1981. For the winter season, the sample for ceiling height, visibility, obstructions to vision, probability of precipitation, and cloud amount consisted of the four winter seasons from 1977-1978 to 1980-1981. These same four seasons, plus an additional partial season of data, November 1981 through January 1982, were used for surface temperature and wind. The sample for the spring season for ceiling height, visibility, obstructions to vision, probability of precipitation, and cloud amount consisted of the five spring seasons from 1978 to 1982. Only the first four seasons were used for derivation of surface temperature and wind prediction equations. Finally, for the summer season: the sample for ceiling height, visibility, obstructions to vision, probability of precipitation, and cloud amount consisted of the four summer seasons from 1978 to 1981 plus June and July of 1982. The surface temperature and wind equations used the same developmental sample except for the data from 1982. The seasons and developmental samples for the PoF equations are specified in Section 3B.

For temperature forecasts, single station equations were developed. Regionalized equations were developed for all other forecast elements. Data from available Alaskan stations, civilian and military, were used to determine the forecast regions.

3. EQUATION CHARACTERISTICS

A. Probability of Precipitation

Regression Estimation of Event Probability (REEP) equations (Miller, 1964) have been derived to determine the probability of occurrence of precipitation $\geq$.01 inch for 6- and 12-h periods. Separate equations were developed for 6-h periods ending at each forecast projection of 12 to 54 hours and 12-h periods ending at each forecast projection of 18, 30, 42, and 54 hours from 0000 and 1200 GMT. These equations were developed for several regions. Fig. 1 shows the regions used to develop the fall, winter, spring, and summer season equations. The equations are used to predict probabilities of precipitation valid for one of four periods during the day for the 6-h forecasts (0000-0600, 0600-1200, 1200-1800, or 1800-0000 GMT), and for one of two periods for 12-h forecasts (0600-1800 or 1800-0600 GMT).

The potential predictor sets consisted of various forecast fields from the LFM model, derived predictors from the LFM model, the sine and cosine of the day of the year, and station latitude and longitude. For all projections, weather elements from surface observations were used as predictors. Backup equations were derived for all projections. The observed weather elements used as predictors were ceiling, total sky cover, visibility, weather, dew point, and wind components. Mean relative humidity, precipitation amount, wind components, vertical velocity, precipitable water, and constant pressure height were screened from the LFM model at various levels. Vorticity, thickness of various layers, dew point depression, vorticity advection, temperature advection, wind divergence, and several stability indices were derived from LFM fields.

Each equation has 12 terms. To provide more consistent forecasts, equations for a given 12-h period were derived simultaneously with those for the two corresponding 6-h periods. With this procedure, all three equations use the same predictors, but, of course, the individual regression coefficients differ. Analysis of the equations shows that nearly all potential predictors are selected for one projection or another. The surface observations are of great importance only for the first 12-h period; in particular, the current weather is by far the most important predictor from the surface observations. For longer range projections, the surface observations become less important, but were still selected as far out as the 54-h projection. The most important LFM predictors were mean relative humidity, vertical velocity, precipitation amount, and relative vorticity.

Maglaras (1982) gives further details regarding the derivation of the PoP prediction equations for Alaska.

B. Conditional Probability of Frozen Precipitation

REEP equations were developed to determine the conditional probability of occurrence of frozen precipitation. The probability forecasts are conditional because they assume precipitation will occur; i.e., only precipitation cases were included in the development sample. In this system, "frozen" precipitation is defined as some form of snow or ice pellets; freezing rain and mixed rain and snow are included with rain and drizzle in the "unfrozen" category. Separate sets of equations were derived for each forecast projection of 12 to 54 hours from both 0000 and 1200 GMT, and for each of three different geographic regions. Fig. 2 shows the regions used to develop the cool and warm season equations. The cool season (November-March) equations were developed on five seasons of data (1977-78 through 1981-82). The warm season (April-October) equations were developed using approximately five seasons from 1977 to 1981. All equations predict probabilities of frozen precipitation valid at specific times each day (i.e., 0000, 0600, 1200, or 1800 GMT).

The potential predictor sets consisted of various forecast fields from the LFM model, derived predictors from the LFM model, station latitude and longitude, station elevation, and sine and cosine of the day of the year. For all projections and for both the cool and warm seasons, weather elements were also screened from surface observations. Forecast fields from the LFM included wind components at various levels. Six other transformed LFM predictors were also used, including 1000-500 mb thickness, 1000-850 mb thickness, 850-500 mb thickness, 850-mb temperature, 850-mb wet-bulb temperature, and boundary layer potential temperature. These fields were transformed through application of the 50% value and the spread constant for each station. Both of these constants were obtained by fitting an S-shaped logit curve (Brelsford and Jones, 1967; Jones, 1968) to the data. The 50% value is that value which indicates a 50-50 chance of frozen precipitation for a station, provided precipitation occurs. The spread constant defines the shape of the logit curve; that is, for a given predictor, some curves are quite steep while others are quite shallow depending on the station. The observed weather elements used as predictors were temperature, dew point, and wind components.

The equations were derived by forcing three transformed LFM predictors into the equations, and then allowing the screening regression process to continue until a maximum of 12 terms had been selected. For both seasons and for most projections, the 1000-850 mb thickness, 850-mb wet-bulb temperature, and 850-mb temperature were forced as the first three predictors. The only exceptions were the 6- and 18-h projections where the boundary-layer potential temperature was used instead of the 850-mb wet-bulb temperature. An analysis of the equations for all projections and regions shows that all the predictors were selected for one projection or another. However, the observed surface temperature and dew point (generally in the shorter range projections), 1000-850 mb thickness, 850-mb temperature, 850-mb wet-bulb temperature, and boundary-layer potential temperature accounted for most of the reduction in variance.

Maglaras (1983a) gives further details about the derivation and use of the PoF prediction equations for Alaska.

C. Ceiling Height, Cloud Amount, Visibility, and Obstructions to Vision

The REEP technique was applied to develop equations to predict the eight categories of ceiling height, four categories of cloud amount, five categories of visibility, and four categories of obstructions to vision shown in Table 2. Separate sets of equations were derived for each forecast projection of 12 to 54 hours from both 0000 and 1200 GMT, and also for each of several different geographic areas. Fig. 3 shows the regions used to develop the fall, winter, spring, and summer equations. All of the equations predict probabilities of each weather element valid at specific times each day (i.e., 0000, 0600, 1200, or 1800 GMT).

Predictor sets for ceiling height, cloud amount, visibility, and obstructions to vision consisted of various forecasts fields from the LFM model, weather elements from surface observations, and several geo-climatic predictors. From the LFM model, we used fields of relative humidity, precipitable water, precipitation amount, wind components and speed, vertical velocity, constant pressure height, temperatures at various levels, vorticity, moisture convergence, temperature/dew point differences, thickness of various layers, and several stability indices. From the surface observations, we offered temperature, weather, ceiling, visibility, cloud amount, and wind components. The geo-climatic predictors included the sine and cosine of the day of the year, station latitude and longitude, and the long-term station climate. For climate, we used monthly values of the frequency of occurrence of ceiling height below 1500 feet and/or visbility less than 3 miles at each of the various stations.

For projections out to 48 hours both primary and backup equations were derived. Each equation contains 20 terms. An analysis of the equations for all projections and regions shows that nearly all potential predictors were selected for one projection or another. For the short-range predictions

(12h-24h), surface observations were the leading predictors. For longer projections, surface observations become less important, although observed predictors were selected at all projections for the majority of the regional equations. LFM predictors chosen most often were those associated with the moisture field--boundary layer and mean relative humidity, precipitable water, temperature/dew point differences--followed by those from the motion field--vertical velocity, wind speeds, and vorticity. For visibility and obstructions to vision equations, LFM predictors from the lower levels of the atmosphere tended to be chosen more often than for ceiling height. In addition, geo-climatic predictors were chosen more frequently at the later projections.

Maglaras (1983b) contains further details regarding the derivation of the ceiling height, cloud amount, visibility, and obstructions to vision forecast equations.

D. Surface Wind

The surface wind is comprised of separate equations derived simultaneously for the u and v components, and the speed, s. This was done in order to enhance consistency between the ensuing forecasts of speed and direction (determined from the components). Separate sets of prediction equations were derived for each forecast cycle, season, station, and projection (12, 18, 24, 30, 36, 42, 48, and 54 hours). These equations produce forecasts for 1-min average winds which are valid at specific times. However, because some stations are closed at certain times, we are unable to generate forecasts for these projections, and thus forecasts are not made.

The potential predictors offered to the screening technique consisted of selected variables derived from LFM output, archived LFM forecast fields, and sine and cosine of the day of the year. We also screened observed weather elements for the 6-, 12-, 18-, 24-, and 30-h forecast projections. Backup equations were also derived for these five sets by not including surface observations as predictors. The main LFM fields we screened were wind components, vertical velocities, constant pressure heights, temperatures, dew points, and mean layer relative humidities for various forecast projections and levels throughout the troposphere. The variables derived from the LFM output included wind speed, divergence, relative vorticity, stability, and sea-level pressure change (the difference between the forecast pressure at two specific times).

Nearly all the potential predictors offered were selected by the screening regression procedure for one station or another. However, these selections were not uniformly distributed and few patterns appeared. Specifically, observed u, v, and s were chosen often as important predictors at the 12-h projection. Also, the LFM 1000-mb geostrophic and 850-mb wind components were quite important. Any given set of equations for u, v, and s contains the same predictors, but, of course, the individual regression coefficients and constants differ. The screening regression procedure was continued for each station's development as long as the addition of a new term to the equation added at least 0.75% to the reduction of variance for any of the predictands or until a maximum of 12 terms were selected. As a result, some of the equations contain less than 12 terms.

In day-to-day operations, a technique called "inflation" is used to enhance each forecast of speed. This is done because forecasts of speed made directly from the regression equations have a tendency to make too few predictions of speeds greater than about 18 knots (see Carter, 1975). The inflation technique (Klein et al., 1959) increases the variance of the speed forecast to equal (or nearly equal) that of the observed wind. In the process, this transformation generates more predictions of strong winds.

Schwartz (1983) contains further details about the development and use of the Alaskan surface wind prediction equations.

E. Surface Temperature

Operational LFM-based forecast equations were developed for surface temperature, valid at 6-h intervals for projections of 6 to 54 hours for both the 0000 and 1200 GMT forecast cycles. In addition, equations were developed for King Salmon to predict the calendar day max/min temperature. Max/min temperature forecast equations could not be developed for the other Air Force sites since the TDL developmental data did not contain calendar day max/min temperatures for those stations. For development of the surface temperature equations, the temperature reported from the surface observation was the most important predictor. Other important predictors included the cosine of the day of the year and of twice the day of the year. Important LFM predictors included the model forecasts of 850-1000 mb thickness, 850-mb temperature and dew point, 1000-mb dew point, and mean relative humidity.

Dallavalle and Murphy (1983) contains further details about the development and use of the Alaskan temperature prediction equations.

4. MESSAGES AND SCHEDULES

The FOAK bulletin is produced twice each day around 0330 and 1600 GMT. An example of the bulletin is shown below. Guidance forecasts for all weather elements are provided in the sample message:

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HONG FOAK12  LFM-MOS  GUIDANCE          2/15/84  1200  GMT

DY/HR    16/00   16/06   16/12   16/18   17/00   17/06   17/12   17/18   18/00

AKN
POP06        0       0       5       5       5       5      20      20
POP12                2               5              10              30
POF         93      96      92      96      98      85      67      93
MN/MX                        3              25              14              31
TEMP         9       4       7       9      22      21      21      20
WIND      3607    3604    0304    0509    0614    0619    0614    0615
CLDS    2134/3  2323/2  4213/1  2224/3  1126/4  1116/4  2215/4  1225/4
CIG     0023/8  0002/8  0014/8  0024/8  0124/8  0135/8  0124/8  0135/8
VIS     0111/5  0011/5  0111/5  0111/5  0111/5  0111/5  1112/5  0111/5
OBVIS   9000/1  9000/1  9000/1  9000/1  9001/1  9001/1  9010/1  9000/1
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ADQ
POP06      20       20       20       30       60       60       60       60
POP12               40                40                80                80
POF       100       98       98       68       42       18       23       22
TEMP       34       29       29       31       37       36       36       35
WIND     3205     3103     2806     0913     0917     0918     0719     0617
CLDS   0235/3   1216/4   3116/4   0217/4   0019/4   0009/4   0019/4   0019/4
CIG    0047/6   0157/5   0256/6   0268/5   0289/3   0299/2   0389/3   1389/2
VIS    0111/5   0012/5   0123/5   0123/5   0234/2   0135/3   0024/4   0124/3
OBVIS  9000/1   9001/1   8001/1   8002/1   7003/4   7003/4   7003/4   8002/3

PASV
POP06       0        0        5        5        5        5        5       10
POP12                0                 5                10                20
POF        97       98       95       99       97       98      100      100
TEMP        2        1        6       10       16       16       16       16
WIND     0000     0000     0000     0000     0403     0706     1007     0907
CLDS   6211/1   5113/1   6212/1   2323/2   2314/3   2215/4   2215/4   1325/4
CIG    0011/8   0123/8   0012/8   0124/8   0124/8   0025/7   0125/7   0025/7
VIS    0000/5   0111/5   0112/5   0111/5   1111/5   0112/5   0112/5   1122/5
OBVIS  9001/1   9000/1   9001/1   9001/5   9001/5   9001/1   9001/5   8002/1
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The 0000 (1200) GMT forecast cycle message gives the day1 max (day2 min), day2 min (day2 max), day2 max (day3 min) and day3 min (day3 max) for King Salmon only. The calendar day forecasts are identified by the MX/MN (MN/MX) symbols. Temperature forecasts denoted by TEMP, valid for the projections of 12, 18, 24, 30, 36, 42, 48, and 54 hours, are also provided. For those stations and projections where forecasts cannot be made, a value of 999 will appear in the message.

The wind forecasts denoted by WIND, for projections of 12, 18, 24, 30, 36, 42, 48, and 54 hours, are provided for both forecast cycles. The wind is presented in the standard DDFF format. Wind direction (DD), computed from the u and v component forecasts, is given to the nearest 10 degrees. The inflated wind speed (FF), is rounded to the nearest whole knot. Forecasts of calm are denoted by 0000. For those stations and projections where forecasts cannot be made, a value of 9999 will appear.

The 6-h PoP forecasts, denoted by POP06, are given for the 12-18, 18-24, 24-30, 30-36, 36-42, 42-48, and 48-54 hour periods for both forecast cycles. The 12-h forecasts (i.e., POP12) are provided for 06-18, 18-30, 30-42, and 42-54 h forecast periods. Both POP06 and POP12 can be any one of the following percentages: 0, 2, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100.

PoF forecasts (POF) are valid for the same specific times as the wind forecasts, and the probabilities are given to the nearest percent.

Cloud amount forecasts are given in the line denoted by CLDS for the same specific times as the wind forecasts. The first four numbers give single-digit probabilities (to the nearest 10 percent) for the cloud amount categories of clear, scattered, broken, and overcast. A "BEST" category cloud amount forecast is given following the slash.

Ceiling height forecasts, denoted by CIG are given for the same times as the wind forecasts. The first four numbers give single digit probabilities (to the nearest 10 percent) for the ceiling height categories of $\leq$ 400 ft, $<$ 1000 ft, $\leq$ 3000 ft, and $\leq$ 7500 ft. The "BEST" category ceiling height forecast is given following the slash and may be any of the eight ceiling height categories shown in Table 2.

Visibility forecasts, denoted by VIS, are valid for the same times as the wind forecasts. Again, for each forecast time, the first four numbers give single digit probabilities (to the nearest 10 percent) of the categories listed in Table 3. The "BEST" category, shown following the slash, may be any of the five visibility categories listed in Table 2.

Obstructions to vision forecasts are given in the line denoted by OBVIS for the same specific times as the wind forecasts. The first four numbers give the probability (to the nearest 10 percent) of the categories listed in Table 3. The "BEST" category, given following the slash, indicates one of the first four categories shown in Table 3.

National Weather Service (1983 and 1984) contain further information about the various weather elements which comprise the FOAK bulletins.

5. OPERATIONAL CONSIDERATIONS

Regression equations are dependent on the accuracy of the numerical model predictions used as input. When a forecaster has reason to believe that the model output is possibly in error, the forecaster should modify the guidance accordingly. In addition, forecasters for Alaska should note that the Alaskan Region lies close to the LFM grid boundary. Any known LFM performance problems may be magnified by the proximity of Alaska to the grid boundary.

6. ACKNOWLEDGMENTS

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Table 1. Names and call letters of the 13 Alaskan locations for which FOAK weather element MOS guidance is provided.

Cape Lisburne (PALU)
Galena (PAGA)
Indian Mountain (PAIM)
Tin City (PATC)
Tatalina (PATL)
Eielson (PAEI)
Elemendorf AFB (PAED)
Big Delta (BIG)
Cape Newenham (PAEH)
Cape Romanzof (PACZ)
King Salmon (AKN)
Kodiak (ADQ)
Sparrevohn (PASV)

Table 2. Definitions of categories used for the development of prediction equations for cloud amount, ceiling height, visibility, and obstructions to vision. The blowing category of obstructions to vision includes blowing snow, dust, sand, and seaspray. The fog category also includes ice fog and ground fog.

Category	Cloud Amount (Opaque sky cover in tenths)	Ceiling (ft)	Visibility (mi)	Obstructions to vision (caused by)
1	0-1	≤400	≤7/8	None
2	2-5	500-700	1-2 3/4	Smoke, Haze
3	6-9	800-900	3-4	Blowing, Fog
4	10	1000-2000	5-6	
5		2100-3000	<6	
6		3100-3900		
7		4000-7500		
8		>7500		

Table 3. Definitions of the operational categories used for cloud amount, ceiling height, visibility, and obstructions to vision. The best category of ceiling height is selected from categories 1 through 8 listed in Table 2. For example, if a best category of 5 is selected, 2100-3000 feet is that category picked as most likely to occur. Likewise, the best category for visibility is selected from the visibility categories listed in Table 2.

Category	Cloud Amount (Opaque sky cover in tenths)	Ceiling (ft)	Visibility (mi)	Obstructions to vision (caused by)
1	0-1	≤ 400	≤ 7/8	None
2	2-5	≤ 1000	1-2 3/4	Smoke, Haze
3	6-9	≤ 3000	3-4	Blowing Fog
4	10	≤ 7500	5-6	
5	BEST	Best	Best	Best

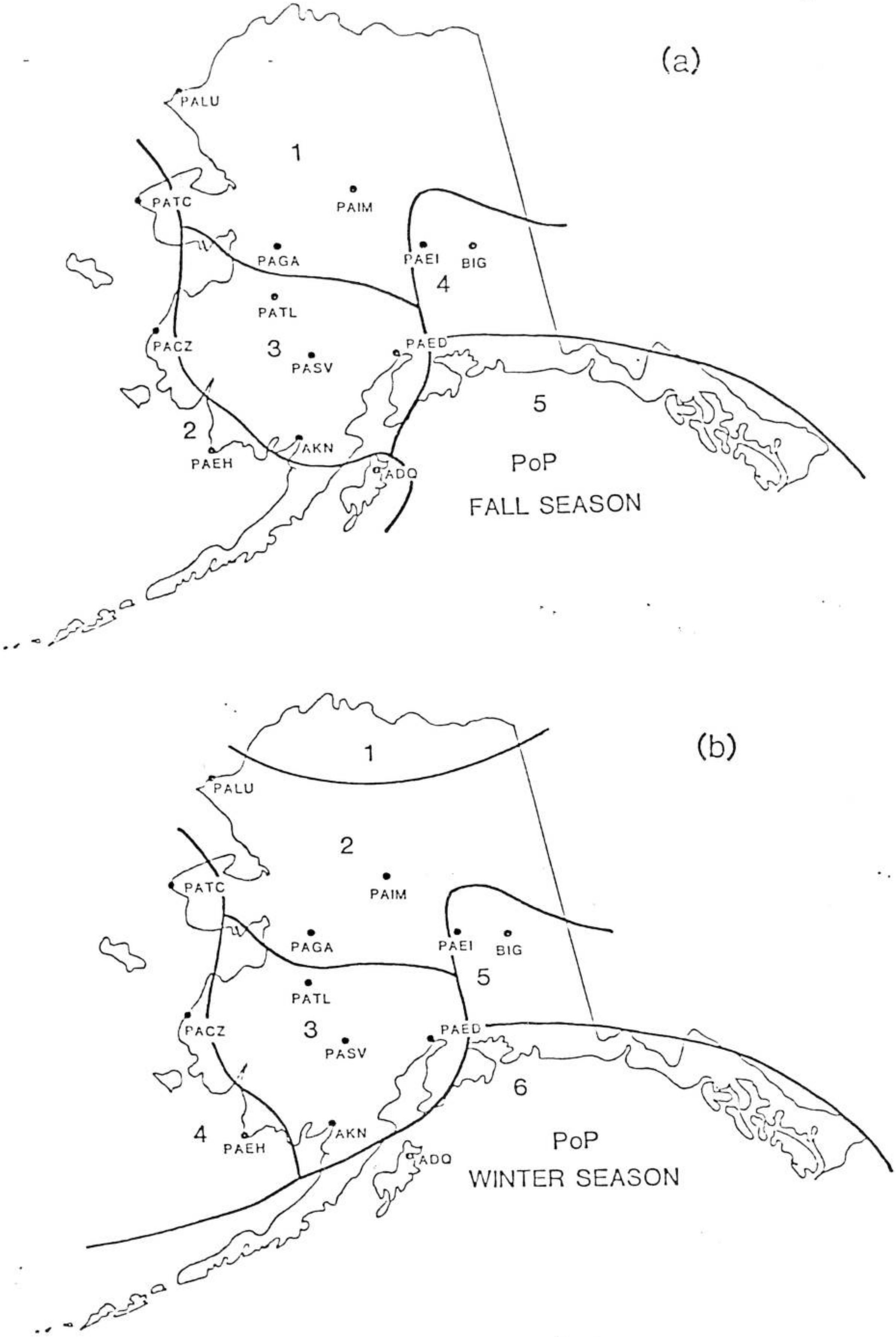


Figure 1. Alaskan military stations with regions used to develop probability of precipitation (PoP) equations for the fall (a), winter (b), spring (c), and summer (d).

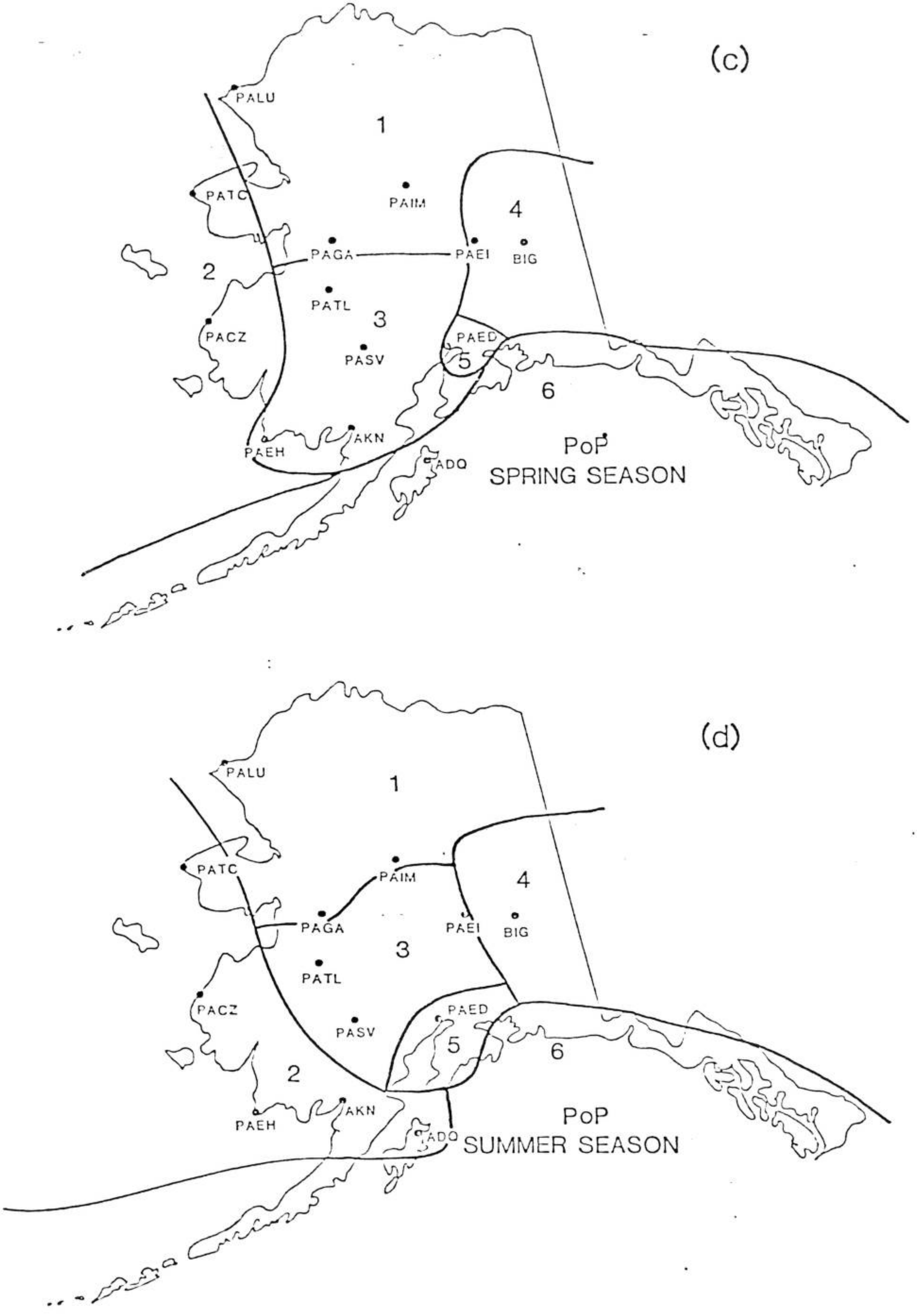


Figure 1. (Continued.)

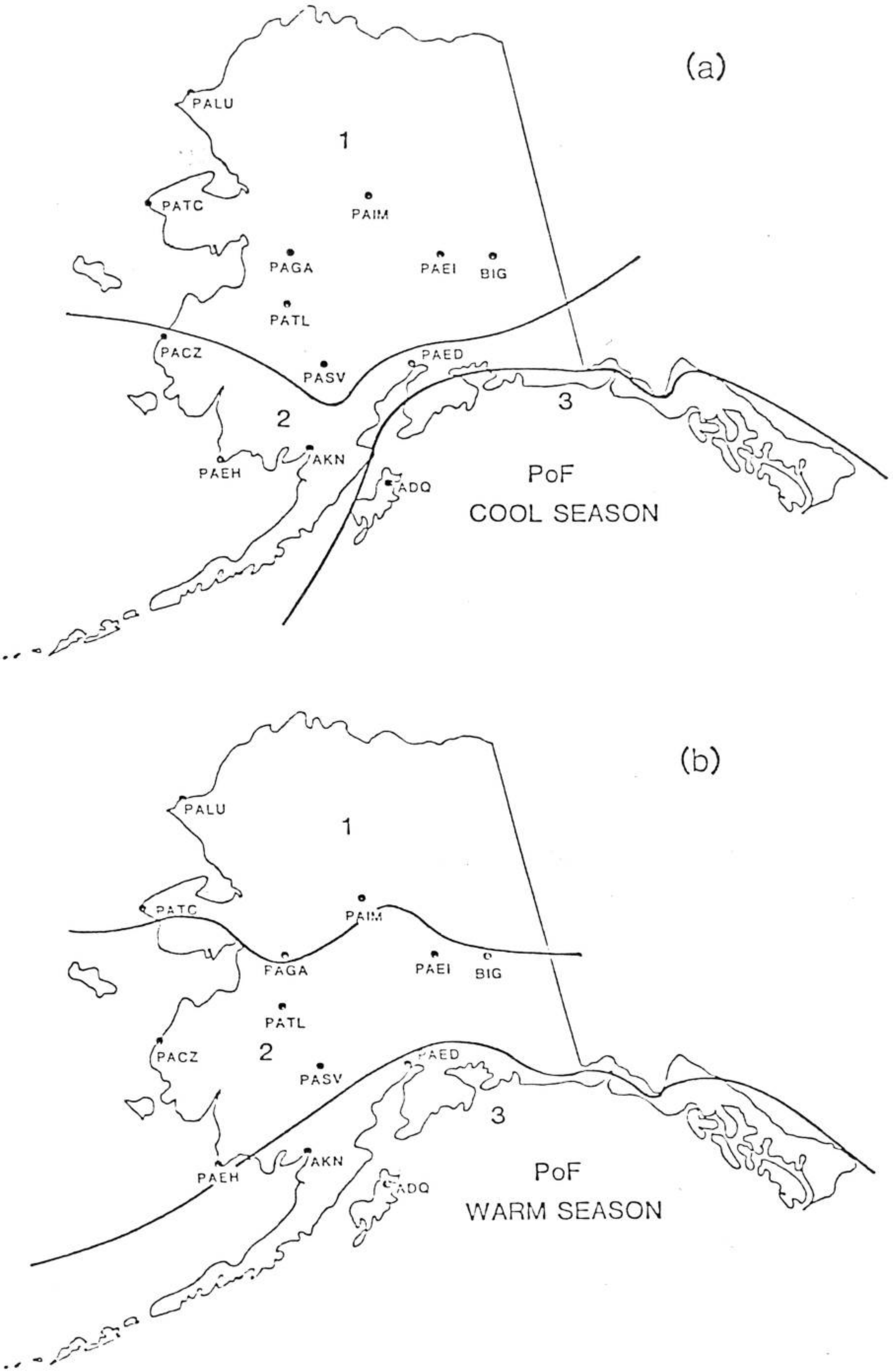


Figure 2. Alaskan military stations with regions used to develop conditional probability of frozen precipitation (PoF) for the cool season (a) and warm season (b).

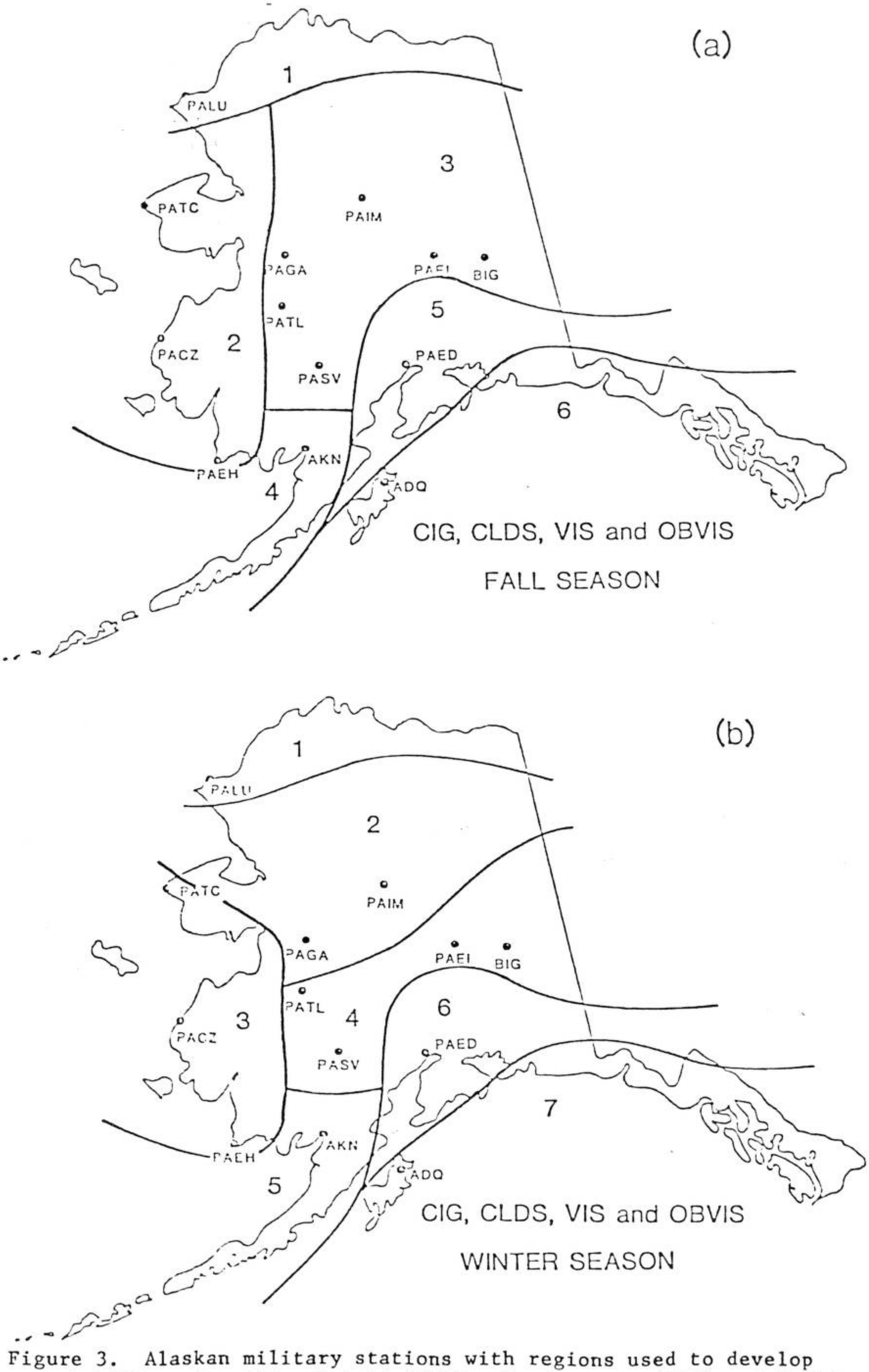
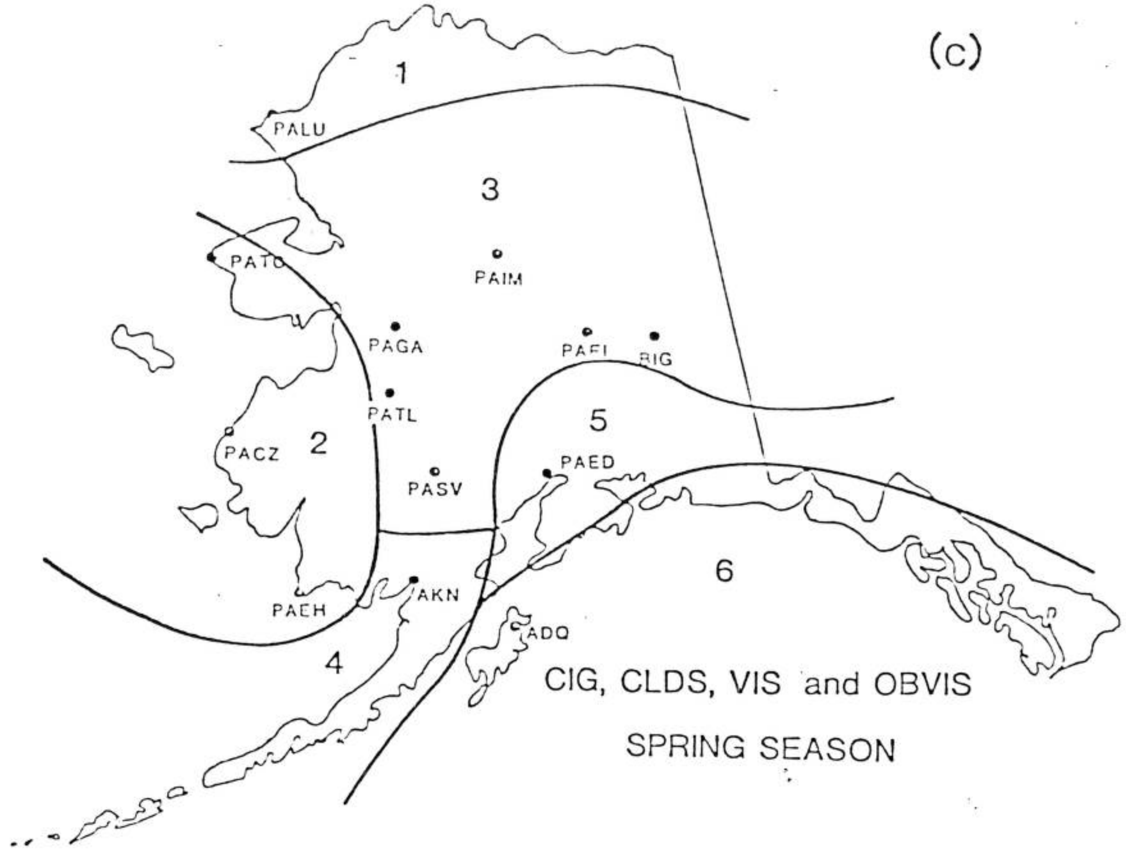


Figure 3. Alaskan military stations with regions used to develop probability of ceiling height (CIG), cloud amount (CLD), visibility (VIS, and obstructions to vision (OBSVIS) equations for the fall (a), winter (b), spring (c), and summer (d).



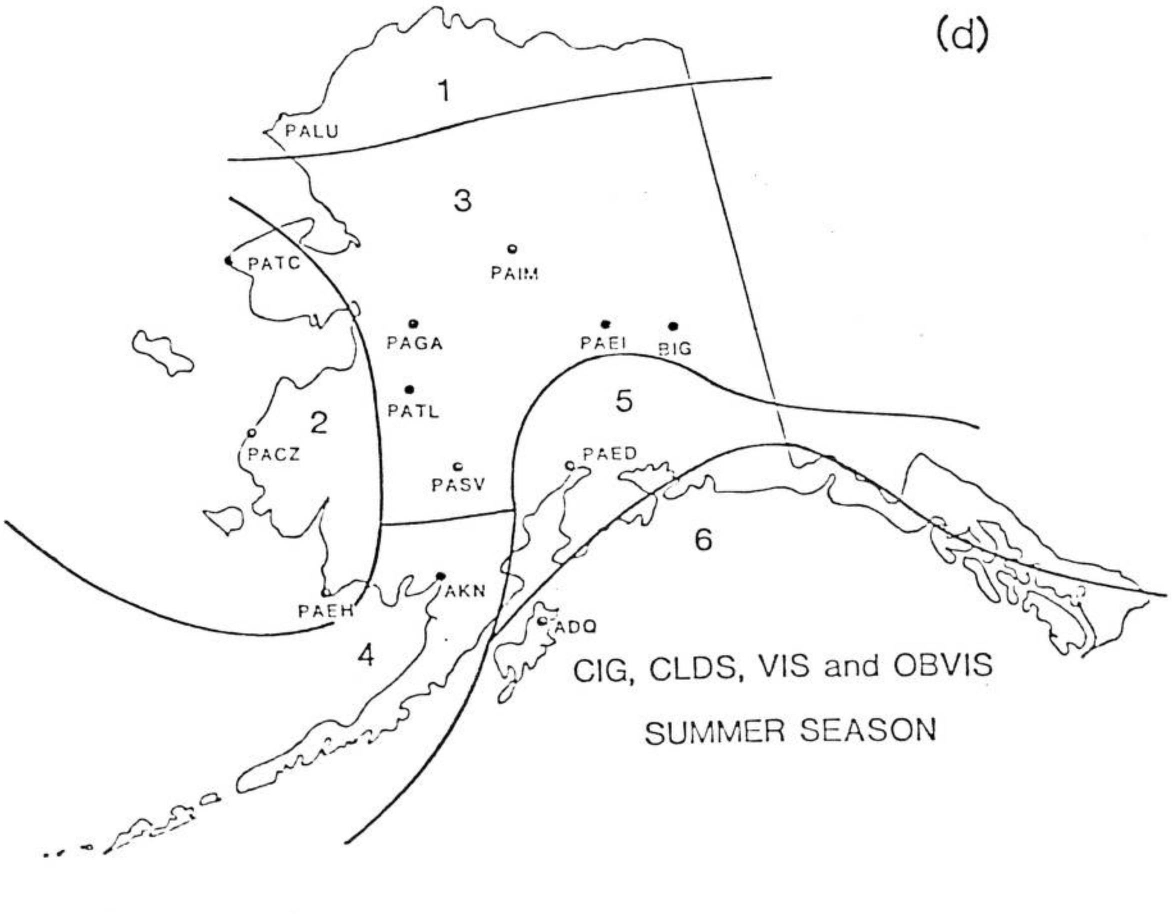


Figure 3. (Continued.)