# Marine Climatology of the Bering Sea

2

James E. Overland

Pacific Marine Environmental Laboratory/NOAA
Seattle, Washington

ABSTRACT

The climate of the Bering Sea is strongly related to the presence and movement of marginal sea ice. In winter, weather elements are continental and arctic in character, being replaced by maritime influences from the south in summer. In winter this results in north to easterly winds,[1] a tendency for clear skies, and substantial diurnal temperature range. Summer is characterized by a progression of storms through the Bering rather than fixed weather types, producing increased cloudiness, reduced diurnal temperature range, and winds rotating through the compass with a slight tendency for southwest.

## INTRODUCTION

The climate of the major portion of the Bering Sea can be classified as "polar oceanic." The system of Köppen and Geiger (1930) classifies "polar" as a geographic region in which the mean monthly temperature for the warmest month is 10 C or less. This is valid for all but the inner region of Bristol Bay. Estienne and Godard (1970) further divided Köppen's classification into five subclasses. The "polar oceanic" region is described as being humid with annual precipitation of from 300 to 500 mm, fairly uniformly distributed over the seasons. This contrasts with the Beaufort Sea which is "polar with a large range of temperature." The Beaufort Sea has less annual precipitation than polar oceanic and greater temperature and precipitation contrasts between summer and winter.

The Bering Sea is affected by arctic, continental, and maritime air masses. In summer the entire region is normally under the influence of maritime air from the Pacific. The southern portion of the Bering Sea is most frequently under the influence of maritime air, except for January and February (Grubbs and McCollum 1968), when normally a strong flow of air from the north and east brings continental and arctic air to most of the area. Arctic air also persists in spring and fall in the northern sector. Using the predominance of the arctic high-pressure air mass over the northern Bering Sea as the indicator, the winter circulation pattern persists for nine months, September through May.

A major influence of the general circulation on the area is the region of low pressure normally located in the vicinity of the Aleutian chain, referred to as the Aleutian Low. On monthly mean pressure charts this appears as a low-pressure cell normally oriented with the major axis in an east-west direction. This is a statistical low, indicating only that pressures are generally lower along the major axis as a result of the passage of low-pressure centers or storms. Storms are most frequent in this area and are more intense there than in adjacent regions. The most frequent track or trajectory of movement of these storms is along the Aleutian Islands and into the Gulf of Alaska in winter, and along the same general path in the west but curving northward into the Bering Sea in summer. The monthly frequency of low-pressure centers in the southern Bering Sea is slightly higher in winter (generally four to five) than in summer (three to four). However, winter storms are much more intense.

In winter the most frequent airflow is northeasterly around the northern side of the low-pressure cell present at some location along the Aleutian chain. In summer, with the movement of lows into the Bering Sea, a more southwesterly mean flow develops over the lower two-thirds of the region. In the Aleutian chain in winter and during the summer in the southern Bering Sea, frontal activity can be severe as very cold arctic or continental air comes in contact with the warm air from the Pacific Ocean, forming a sharp discontinuity. In the northern Bering

[1] Wind convention names the direction from which the wind is blowing.

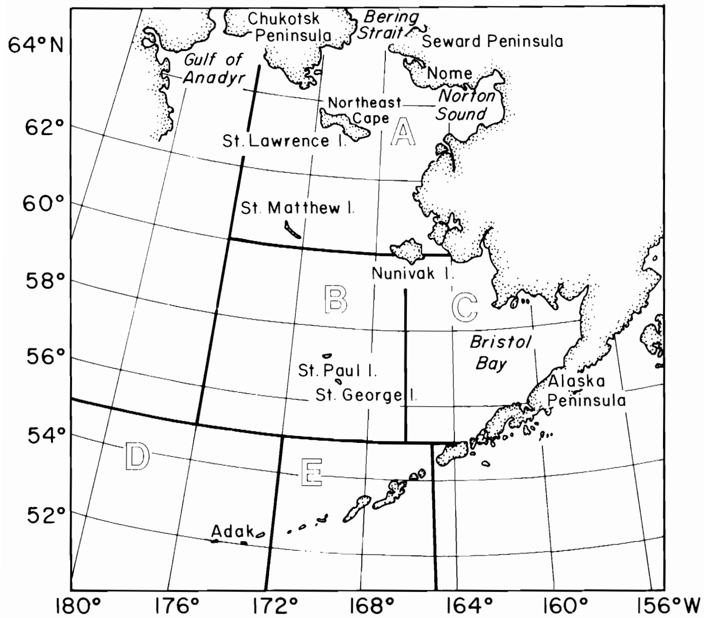

Figure 2-1. Location map for the eastern Bering Sea.

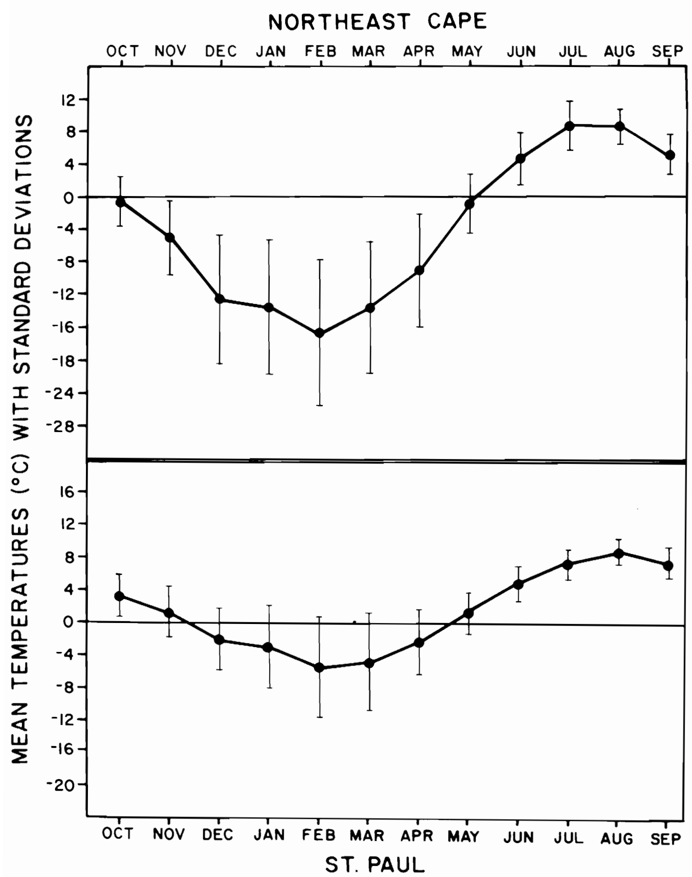

Figure 2-2. Annual temperature march and monthly standard deviations for Northeast Cape and St. Paul. There is greater annual range at the northern station.

Sea, polar air masses usually predominate for extended periods of time. Frontal systems moving through the area generally represent a line of discontinuity of air masses of similar character, and consequently are much less severe.

The ice pack dominates the Bering Sea from January through May (McNutt and Pease, this volume). After April the ice pack moves progressively northward and by July it is generally north of Bering Strait. The Bering Sea is ice free from July through September. Ice begins moving southward during October and reaches its southern limit near 60°N by February or March. The seasonal migration of the ice pack is extremely important for the climate of the Bering Sea. It introduces a continental influence during winter which allows cold arctic and continental air to establish itself over the ice-covered sea with wide ranges in daily and seasonal temperatures. This contrasts sharply with the entire Bering Sea in summer and the southern portion in winter, which have a maritime climate with a more uniform daily temperature regime and enhanced precipitation.

## CLIMATOLOGICAL SUMMARY

Data for this section were obtained from *Climatic Atlas of the Outer Continental Shelf Waters and Coastal Regions of Alaska: Volume II—Bering Sea* (Brower et al. 1977) and *A Climatological Guide to Alaskan Weather* (Grubbs and McCollum 1968). The data periods in Grubbs and McCollum "contain at least 10 years" while Brower et al. specify the number of observations. Fig. 2-1 is a map locating stations and marine areas used in the figures and tables. Marine areas A to E designate regions where ship reports form the climatological base.

### *Temperature*

Since this region is oriented north-south, there is some latitudinal variation in temperature. This is more noticeable in winter when the total amount of sunshine varies from several hours in the south to almost none in the north. In addition the southern portion in winter may come under the influence of southeasterly flow of fairly warm, moist air from the north Pacific, while the northern portion is under the influence of cold, dry air generally flowing out of the interior of northern Alaska. While the ice serves as a barrier between air and sea, some heat is diffused through the ice from the much warmer ocean so that, although the arctic air is very cold, temperature minimums do not reach the low extremes of the Alaskan interior.

Fig. 2-2 plots the mean monthly temperatures and standard deviations for Northeast Cape (approximately 3,000 observations per monthly group) and for St. Paul (over 4,000 observations per monthly group) after Brower et al. (1977). Fig. 2-2 shows much larger annual range in the north. The August-minus-February temperature difference is 25 C, versus a 14 C difference at St. Paul. The standard deviation of monthly temperatures at Northeast Cape is greater in winter than in summer and greater than the standard deviations for all seasons at southern stations. Table 2-1 presents the mean maximum and minimum temperatures (°C) by month for Northeast Cape and Adak after Grubbs and McCollum (1968). When the mean daily ranges of temperatures (monthly mean maximum minus monthly mean minimum) for summer and winter are compared, Northeast Cape shows an 8 C range in late winter and a 4 C range in summer, while the range at Adak is 4-5 C, independent of season. The greater temperature ranges at Northeast Cape point to a continentality in the north during winter which is replaced by a maritime climate in summer.

TABLE 2-1

Maximum and minimum mean monthly temperatures and monthly precipitation for Northeast Cape and Adak

Temperatures in °C Precipitation in mm

NORTHEAST CAPE

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean maximum temperature | −12 | −13 | −9 | −6 | 2 | 7 | 11 | 10 | 7 | 2 | −3 | −13 |
| Mean temperature | −16 | −17 | −13 | −9 | −31 | 4 | 8 | 8 | 5 | 0 | −4 | −15 |
| Mean minimum temperature | −19 | −21 | −17 | −13 | −3 | 1 | 6 | 6 | 3 | −2 | −7 | −17 |
| Mean total precipitation | 12.9 | 10.2 | 21.1 | 9.4 | 13.7 | 12.9 | 28.2 | 98.8 | 113.0 | 56.4 | 39.9 | 14.5 |

ADAK

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean maximum temperature | 3 | 3 | 4 | 6 | 7 | 9 | 12 | 13 | 11 | 8 | 5 | 3 |
| Mean temperature | 1 | 1 | 2 | 3 | 5 | 7 | 9 | 11 | 9 | 6 | 3 | 1 |
| Mean minimum temperature | −1 | −2 | −1 | 1 | 3 | 5 | 7 | 8 | 7 | 3 | 1 | −1 |
| Mean total precipitation | 160.0 | 134.6 | 165.1 | 106.7 | 116.8 | 83.8 | 76.2 | 104.1 | 137.2 | 185.4 | 193.0 | 198.1 |

*Precipitation and cloud cover*

There is a general decrease in the amount of precipitation from south to north because the northern points are more distant from the moisture source, especially in winter. Table 2-1 shows that precipitation at Northeast Cape is low from December through June, when the northern region is dominated by the arctic air mass. There is a sharp spike during August and September, when storm tracks penetrate the northern Bering Sea. Adak has precipitation the year round with an increase in October through December which corresponds to a season of cyclogenesis in the southern Bering Sea.

One of the most important controls effected by cloudiness is of the type of air which is synoptically in possession of the area. In winter the majority of the Bering Sea region is most frequently under northeasterly or northerly flow of cold, dry arctic air. In summer the entire region is under the influence of moist air from a north Pacific air mass. This leads to a larger number of clear days in the northern region in winter. However, even though the arctic air contains only a small amount of moisture, the cold air mass exhibits high relative humidities near the surface. Only a slight amount of lift, for example from a weak storm system, is required for formation of cloud cover. Fig. 2-3 shows the percent of observations by month in which the observed cloud cover was five-eighths or more for Northeast Cape, St. Paul, and Adak (Brower et al. 1977).

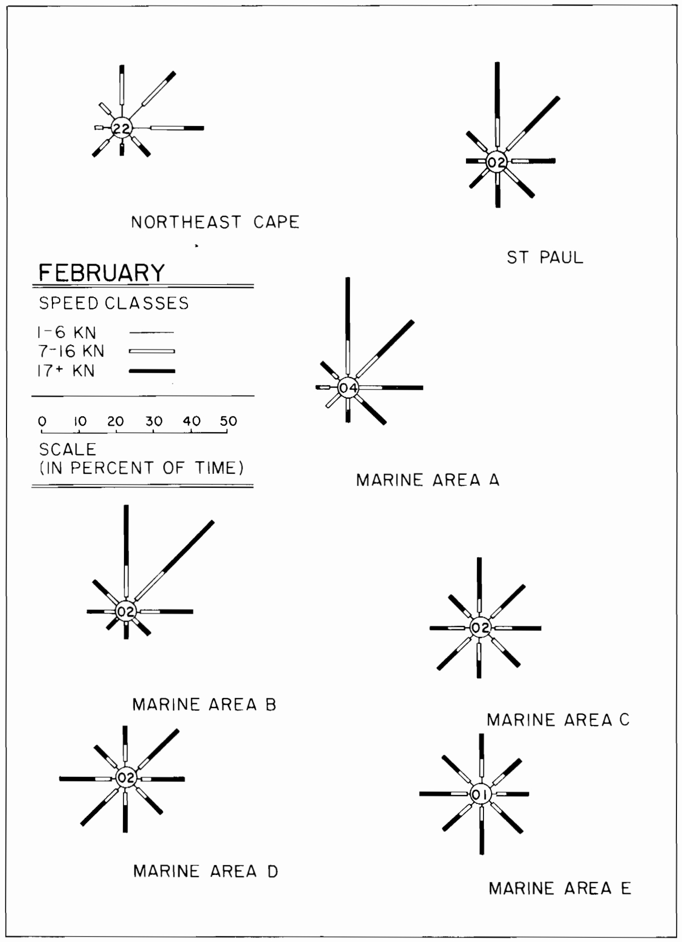


Figure 2-4. February wind roses. (Direction from which the wind is blowing.)

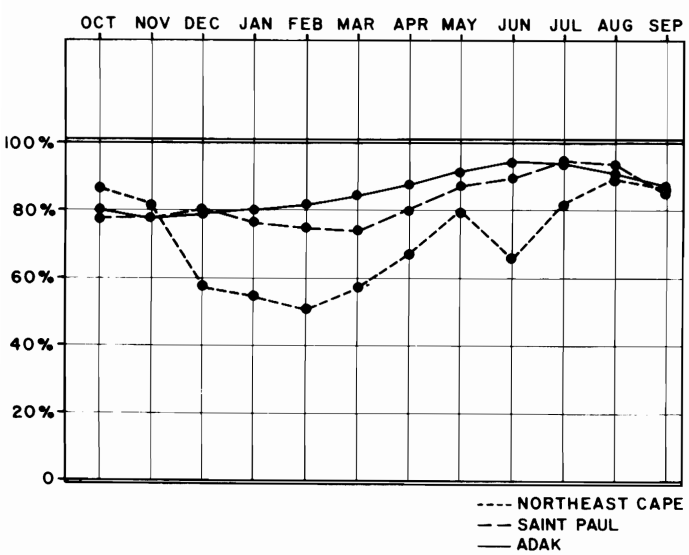


Figure 2-3. Percent of observations reporting five-eighths cloud cover or greater.

*Surface Winds*

Fig. 2-4 shows wind roses for selected locations in the Bering Sea during February and Fig. 2-5 shows roses for the same stations during August. Wind roses show the percentage of observations from each of eight possible directions. The number in the center is the percent of light winds in the record. Each arm is divided into the percent of observations of 1-6 kn, 7-16 kn, and 17 kn or greater from each direction.

In winter the northern stations show a high percentage of winds greater than 17 kn from the north and northeast, while in the south, the winds over marine area C are uniformly distributed over direction with moderately large speeds. This marine rose is indicative of a fairly continuous progression of storms through the area. Wind speeds over the Bering Sea in summer are generally lower than in winter,

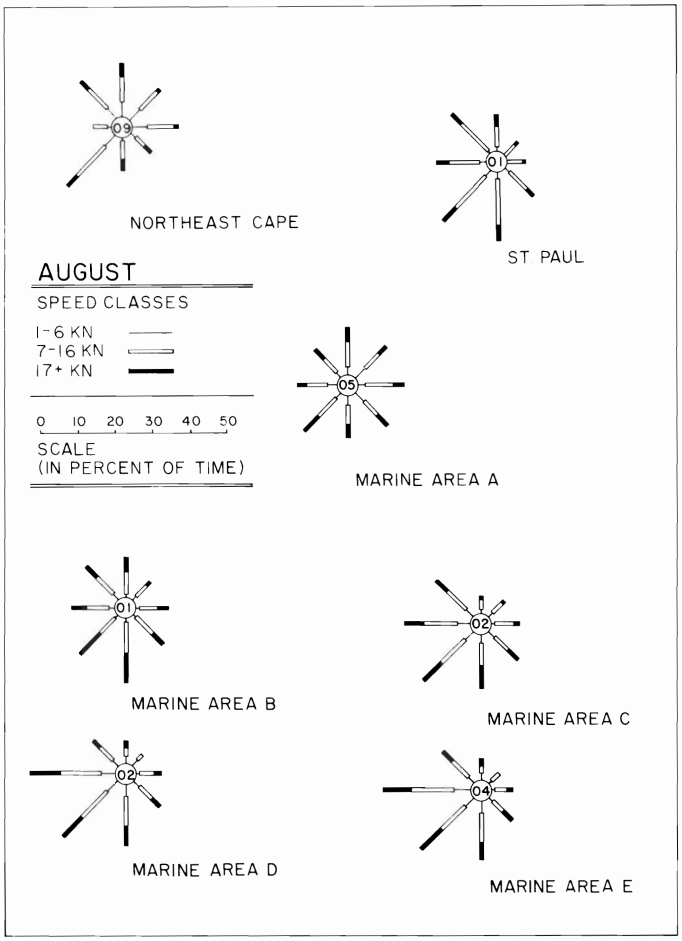


Figure 2-5. August wind roses. (Direction from which the wind is blowing.)

although conditions are seldom calm. Marine area A to the north shows little preferred direction, but the other stations show predominance of south and southwest winds.

*Runoff*

Freshwater inflow to the eastern Bering Sea is primarily from the Yukon, with only minor contributions from other sources, most notably the Kuskokwim. Fig. 2-6 plots the mean monthly discharge rates for the combined Alaska runoff into the Bering Sea and for the Yukon for 10 water-years 1967-77 (U.S.G.S. 1977). The 10-year monthly mean discharge rates show very little flow and variability of flow during the months of December, January, February, March, and April. The months of greatest flow are also the months of greatest variability: May and June.

## CIRCULATION

There are two general approaches to classifying climatological types: a synoptic climatology which regards circulation patterns as an implicit function of the static sea level pressure (SLP) distribution (Barry and Perry 1973), and a kinematic approach in which synoptic weather maps are classified in terms of principal storm tracks (Klein 1957).

Two synoptic climatologies which refer to the Bering Sea are those of Putnins (1966) and Barry (1978). Putnins establishes 22 patterns "in such a way that for every date of this period (1 January 1945 to 31 March 1963) a specific baric weather pattern could be assigned." Unfortunately, Putnins' emphasis centers on continental Alaska and applies only in a general manner to the Bering Sea. Barry developed a synoptic climatology for the Chukchi Sea which has 22 types and includes the maritime region of northern Bering Sea.

Barry states that in winter his Type 1, arctic high pressure with subpolar easterlies at Kotzebue (Fig. 2-7) is dominant and is associated with a low-level atmospheric temperature inversion. Interruptions by anticyclonic systems are the most common. They are associated with cold continental air masses which reinforce the shallow arctic boundary layer. Cyclonic interruptions are less common

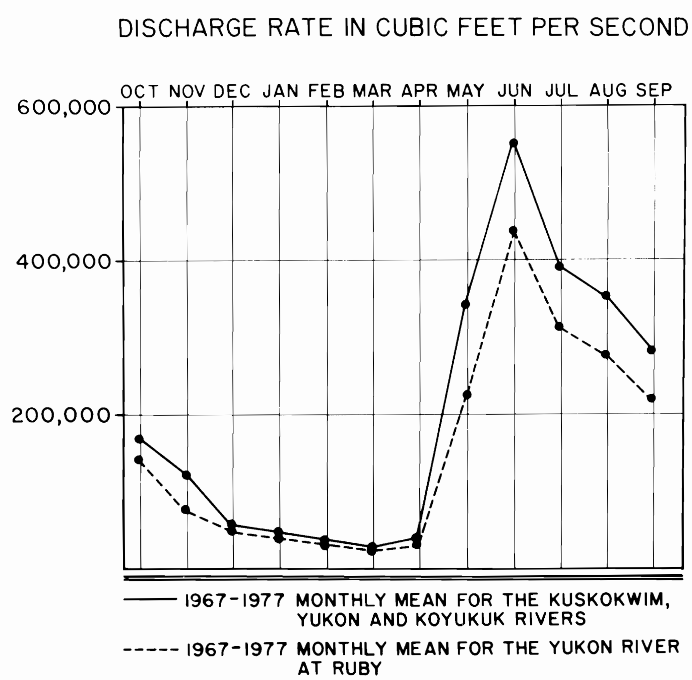


Figure 2-6. Runoff rate as a function of month for the Yukon River and for total runoff into the eastern Bering Sea.

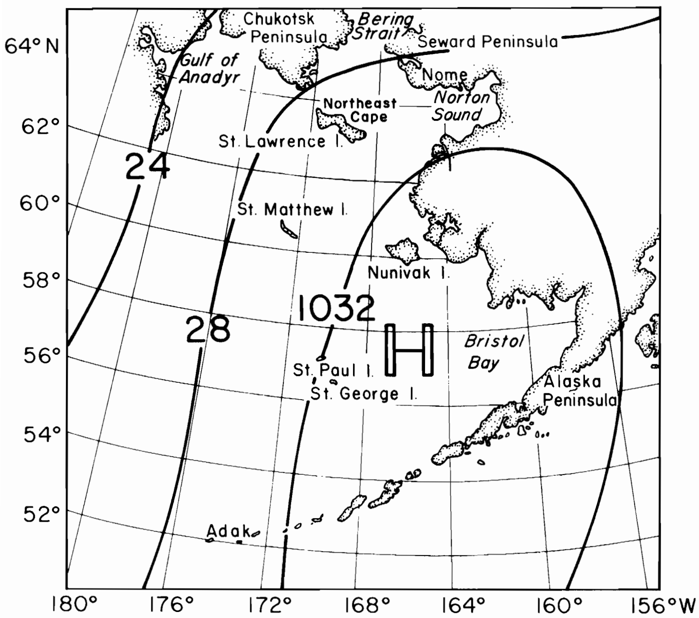


Figure 2-7. Barry's (1978) dominant winter Type 1 sea-level pressure weather pattern.

and bring warm air with larger amounts of cloudiness. Barry states that in summer there is a great variety of types, with both cyclonic and anticyclonic types apparent. Type 3 (Fig. 2-8) is the most common in July and is closest to the mean monthly SLP charts for summer given by Brower et al. (1977); one interpretation is that atmospheric circulation in the

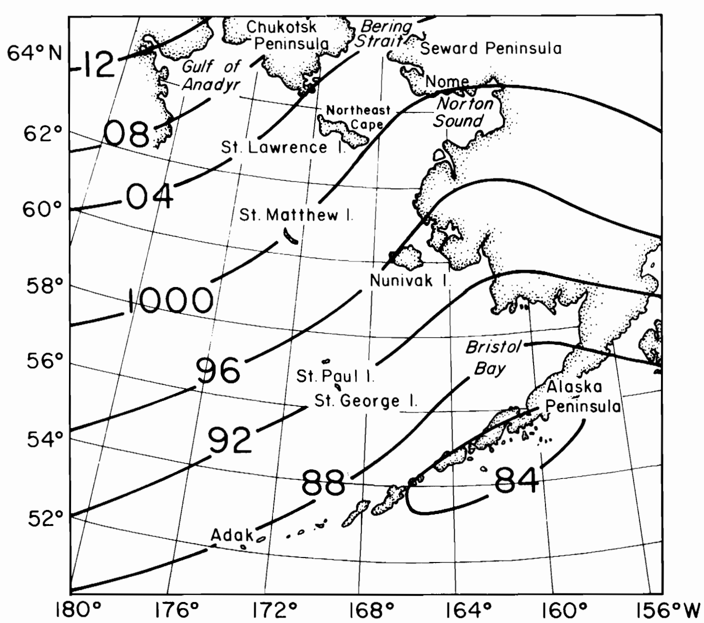


Figure 2-8. A frequently occurring summer weather type, from Barry (1978).

southern Bering Sea can be more readily characterized by mean storm tracks or the presence of low-pressure centers in certain sectors of the region than by static weather types. Fig. 2-9 plots the average number of low-pressure centers observed in a 10° × 10° latitude-longitude area during the nine-year period of record 1966-74. These areas are NW (60°-70°N, 170°-180°W), NE (60°-70°N, 160°-170°W), SW (50°-60°N, 170°-180°W), and SE (50°-60°N, 160°-170°W). It is apparent that southern sectors have two to three times more storms than the northern sectors. However, the monthly variability is high, suggesting that the period of record is too short to make comparisons between months.

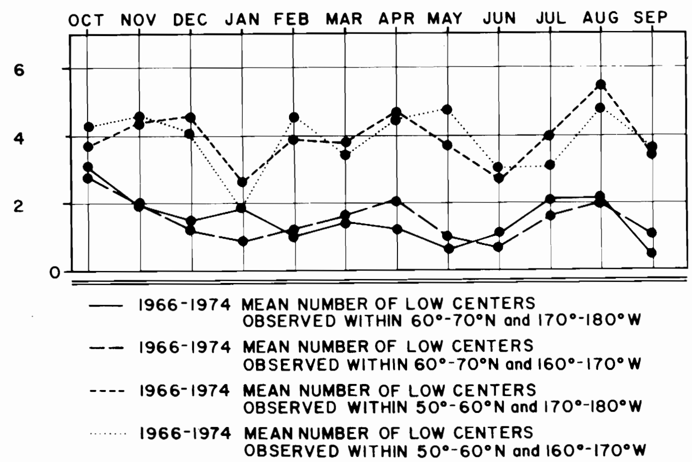


Figure 2-9. Frequency of low-pressure systems by month for the northern and southern Bering Sea.

## CLOUD STREETS

The advection of cold air southward from the north and northeast Bering Sea in winter produces ideal conditions for convective cloud development over the relatively warm waters to the south. The air is virtually unimpeded as it flows south across the ice, and the ice edge forms a sharp line of demarcation where sea temperatures can be as much as 15 C warmer than the air. As the air continues to flow south it is progressively destabilized by the upward transfer of heat and moisture from the ocean.

The most frequently observed patterns are of the type displayed in Fig. 2-10, which shows uniform cloud streets at intervals averaging 5-6 km forming 20-70 km to the south of the ice edge and aligned in the direction of the surface wind (Streten 1975). They extend some 200-300 km downstream, displaying only a small increase in cloud element dimensions.

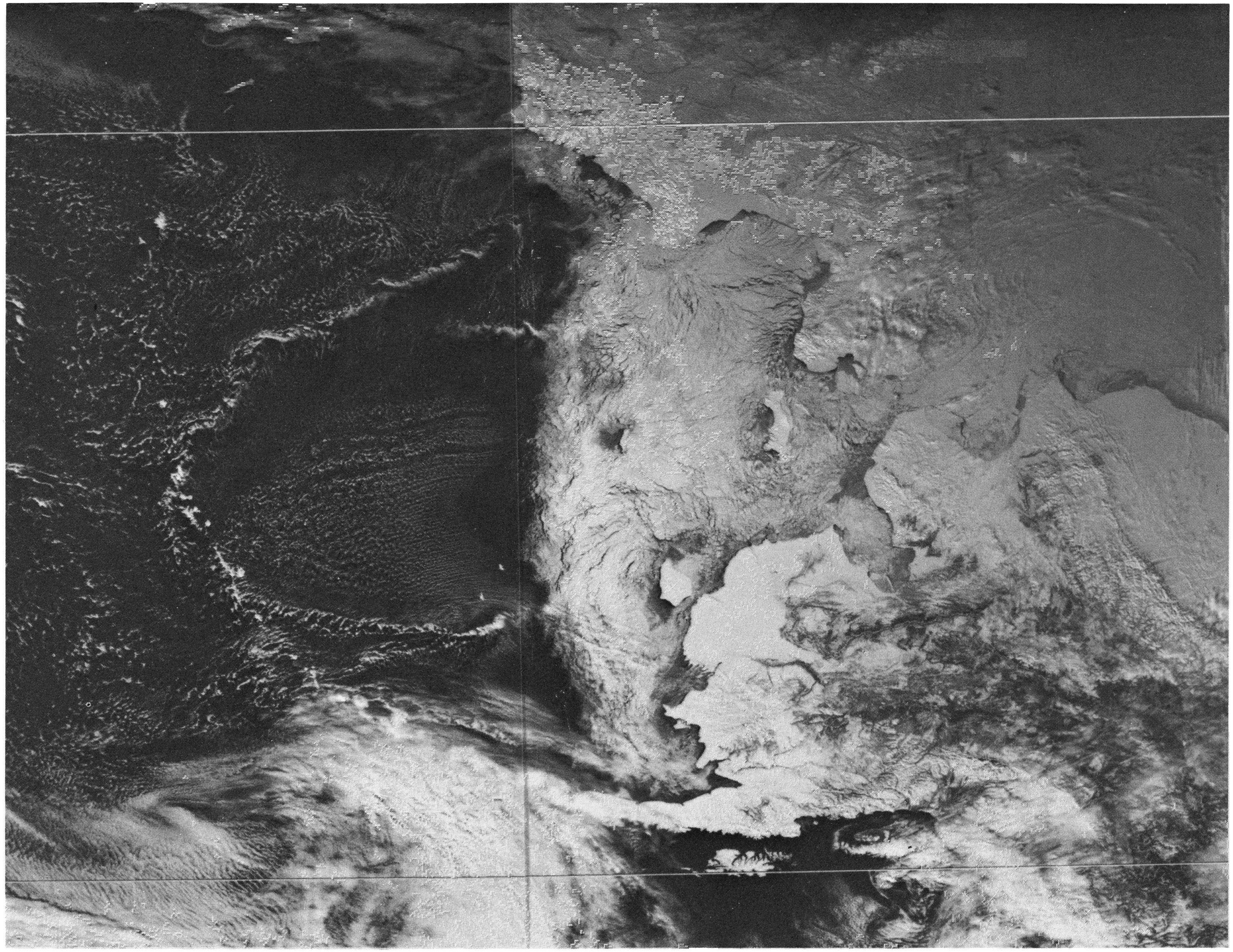

Figure 2-10. Satellite photo from 23 March 1978 showing cloud streets forming south of the ice sheet. Note Alaska to the right.

Beyond this distance there is a sharp transition from parallel streets to an open cell convection pattern with cloud elements 10 km in width separated by 20-25 km. With increasing distance from the source, the open areas grow to 50 km with cells of 20 km.

ACKNOWLEDGMENTS

This research is PMEL contribution No. 446. It was supported by the Bureau of Land Management through interagency agreement with the National Oceanic and Atmospheric Administration, under a multiyear program responding to needs of petroleum development of the Alaskan continental shelf, managed by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) Office. Assistance from S. Schoenberg and the PMEL graphics and word-processing center is gratefully acknowledged. The anonymous reviews of the manuscript contributed to strengthening the final draft.

REFERENCES

Barry, R. G.
1978 Study of climatic effects on fast ice extent and its seasonal decay along the Beaufort-Chukchi coasts. *In:* Environmental Assessment of the Alaskan Continental Shelf IX, Transport, NOAA, Environmental Research Laboratories, Boulder, Colo., 704-719.

Barry, R. G., and A. H. Perry
1973 Synoptic Climatology, Methods and Application. Methuen & Co., London.

Brower, W. A. Jr., H. F. Diaz, A. S. Prechtel, H. W. Searby, and J. L. Wise
1977 Climatic atlas of the outer continental shelf waters and coastal regions of Alaska. AEIDC and NOAA, Anchorage, Alaska.

Estienne, P., and A. Godard
1970 Climatologie. Armand Colin, Paris.

Grubbs, B. E., and R. D. McCollum Jr.
1968 A Climatological guide to Alaskan weather. Scientific Services Section, 11th Weather Squadron, Elmendorf AFB, Alaska.

Klein, W. H.
1957 Principal tracks and mean frequencies of cyclones and anticyclones in the Northern Hemisphere. U.S. Weather Bureau, Research Paper 40.

Köppen and Geiger
1930 Handbuch der Klimatologie. 5 Vols. Berlin.

Putnins, P.
1966 The sequence of basic pressure patterns over Alaska. Studies on the Meteorology of Alaska 1st Interim Report, Environmental Data Service, ESSA, Washington, D.C.

Streten, H. A.
1975 Cloud cell size and pattern evolution in Arctic air advection over the north Pacific. Arch. Met. Geophys. Biokl., Ser. A, 24: 213-28.

U.S.G.S. (United States Geological Survey)
1967-77 Water resources data for Alaska for water year 1977, Part I; Surface Water Records. U.S. Dep. of the Int. Geol. Surv.—Water Res. Div.