

ON THE CLIMATE AND AIR POLLUTION POTENTIAL IN
GLACIER BAY NATIONAL MONUMENT, ALASKA

Final Report

To

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by

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ABSTRACT

Meteorological data have been collected from Goose Cove, Muir Inlet over two summers for the purpose of evaluating the air pollution potential in the glaciated fjords of Glacier Bay. The primary emphasis has been on determining the wind and temperature structure in the near surface air layers of the fjords with special attention to the air lying directly over the water where exhaust pollutants are emitted from cruise ships. The distribution of wind speed and temperature in the lower atmosphere determines the mixing rate of the air and hence its ability to disperse air pollution. Mean wind speeds are low (4.4 mph) and winds blow from the north directly down the inlet. Forced mixing is minimal because of the low wind speeds. Thermal mixing is also minimal as inversions (with gradients as great as $3.0^{\circ}\text{C}/100$ meters) are often present and extend upwards of 200 meters. As a result, it is concluded that the tolerance for pollution is extremely low in the fjords of Glacier Bay.

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INTRODUCTION

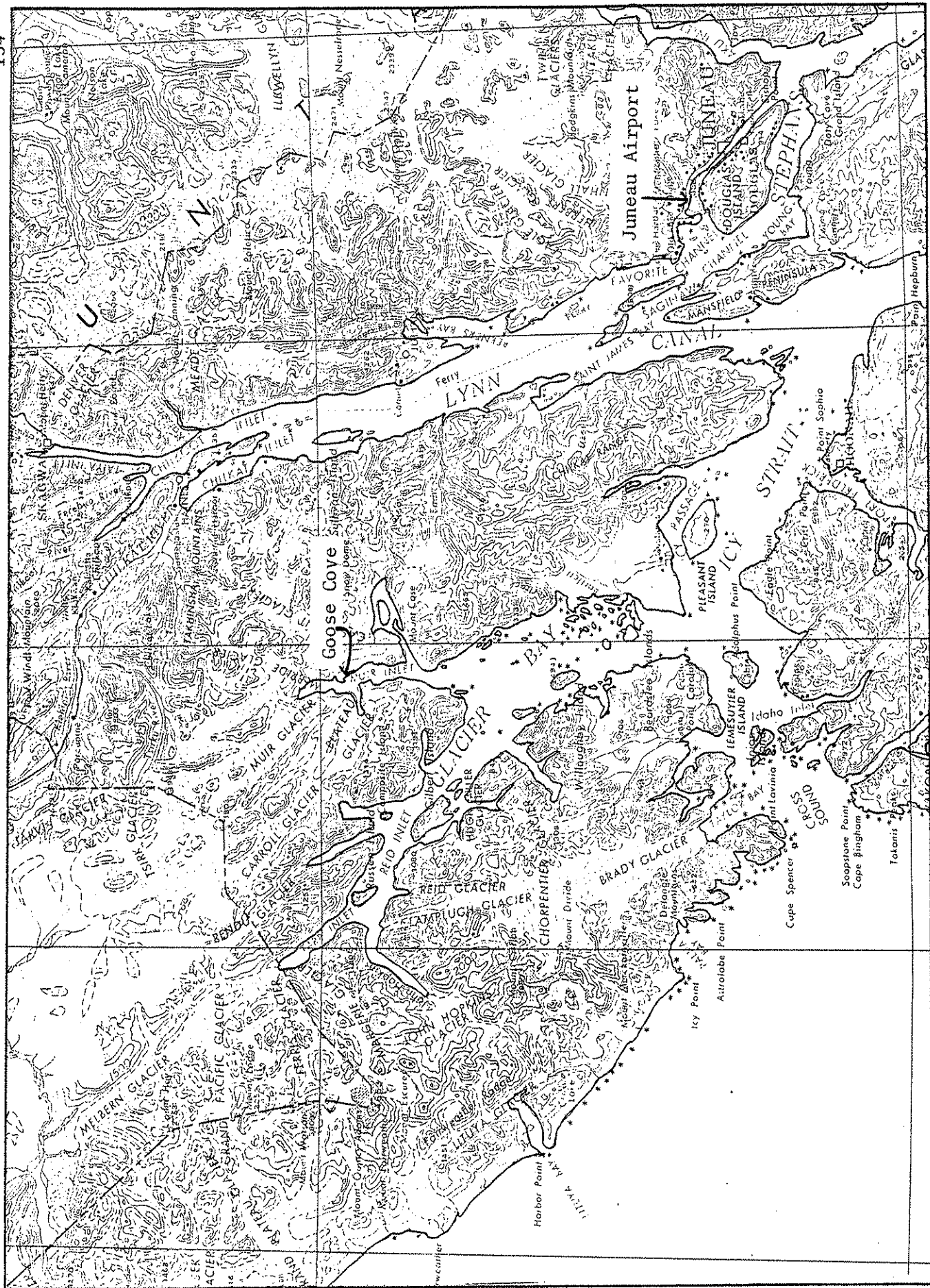
Cruise ship traffic to the upper fjord country of Glacier Bay National Monument has increased dramatically during the last several years. Stack emissions from these ships have been observed to accumulate in the bay as extensive visible haze layers, especially during clear, calm weather. Park service officials were concerned about the deteriorating air quality of the Monument and began to discuss the problem with us during the winter of 1975-76. The outcome of these discussions was an agreement for us to conduct a reconnaissance study to assess the air pollution potential of upper Glacier Bay and determine whether a more extensive study was required. The reconnaissance study, done during the summers of 1976 and 1977, is reported here.

The general climate of Glacier Bay National Monument is maritime (Searby, 1968). The summers are cool (Table 1), while the winters are relatively warm, at least when compared with more continental areas of Alaska. The minimum temperature hardly drops below -12°C . Wind velocities are normally high, owing to the frequent cyclonic activity in the Gulf of Alaska. However, at Goose Cove, our main station, this is not the case, as it is protected by mountains from the Pacific Ocean. This is a typical example where the mesoscale climate dominates the general one. The amount of cloudiness is high; precipitation is frequent. There is a strong gradient in the amount of precipitation, when going from the Pacific site (greater than 2500 mm annually) inland. Juneau, for example, reports only about half of this amount. As the topography of Glacier Bay National Monument is very diversified, the climate changes also from location to location. Only a very limited amount of past meteorological data exists, which is nicely summarized by Streveler and Paige (1971).

138°

136°

134°



59°

2

59°

58°

58°

138°

136°

134°

Table 1

Average and Mean Extreme Temperatures for Selected Sites at Glacier Bay National Monument and Juneau: Summer 1976 and 1977.

1976	Goose Cove Ave. Max. Min.	Alder Ave. Max. Min.	Composite Island Ave. Max. Min.	Juneau Airport Ave. Max. Min.
June (12) 15-22, 27-30	10.2 15.2 5.9	7.5 11.8 4.5	9.5 14.3 5.8	12.1 16.9 7.1
July (21) 1, 2, 6-24	11.4 16.1 6.5	7.7 11.8 5.0	9.4 14.3 5.9	12.9 17.6 8.1
August (9) 4, 5, 18-21, 30, 31	9.3 13.5 6.3	9.2 12.4 7.1	10.2 13.7 6.9	13.1 16.5 9.3
September (5) 1-5	7.2 12.3 3.1	7.7 11.6 5.3	8.2 12.9 5.6	10.9 14.9 6.4
1977	Goose Cove Ave. Max. Min.	Alder Ave. Max. Min.	XXXXXXXXXXXXXXXXXX	Juneau Airport Ave. Max. Min.
June 10-30	9.8 14.4 5.3	9.3 13.3 5.3		13.0 17.1 9.0
July 1-15, 19-31 (Goose) 14-31 (Alder)	10.1 14.7 5.5	8.9 12.0 5.8		18.1 9.6 13.8
August	9.3 14.8 3.7	10.1 14.0 6.2		15.2 20.2 10.1
September 1-8	7.7 13.9 1.5	9.1 12.0 6.1		12.1 16.1 8.1

DESCRIPTION OF SITE AND MEASUREMENTS

We chose Goose Cove as our main station. It is located two-thirds of the way up Muir Inlet at 58°57'N; 136°6'W (Figure 1). At Goose Cove, two measuring sites were used: Site 1 was at sea level, and Site 2 was on top of an adjacent hill at an altitude of 127 meters. The following records were obtained from these sites during 1976.

Goose Cove No. 1 (approximately sea level about 25 meters from shore).

Sky cover - visual observations every morning from 1 June to
20 September.

Precipitation - measured every morning from 1 June to 15 September.

Temperature - measured every morning from 1 June to 15 September.

Temperature - continuous record of thermograph (weekly record),
7 June to 20 September.

Temperature - measured over water on a raft, 14 August to 12
September, 30 days total.

Humidity - continuous record of hygograph (weekly record),
7 June to 20 September.

Radiation - continuous record of Belfort recording pyrlieliograph,
(weekly record), 1 June to 20 September.

Wind - speed only, measured every morning as total wind run per
day (diurnal variation and direction were recorded at
Goose Cove Site 2).

Goose Cove No. 2 (127 meter altitude on hill top; also referred to as
"Alder" Site because of the dense growth of alder trees).

Temperature - continuous record of thermograph, (weekly and
monthly records), 1 June to 12 September.

Humidity - continuous record of hygrograph (monthly record)

12 June to 12 September.

Wind - continuous record of windspeed and direction - Woelfle

type instrument (monthly records), 12 June to 12 September.

The third site was established at Composite Island, (58°53'N; 136°33'W) in Tarr Inlet. It consisted solely of a thermograph mounted in an instrument shelter at sea level, producing weekly charts, between 8 June to 6 September.

Supplementary measurements of air quality (Aitken nuclei counts and other measurements) and water temperature were made at other parts of the monument as opportunity permitted.

For the 1977 summer research, we made the following changes in the measuring program:

- a) Station No. 1 was moved from the beach site to a raft directly over the water in the fjord. The analyses of the data from 1976 had revealed that there was a well-developed microclimate over the beach which was not typical of the air above the fjord itself. A two-pen thermograph was also used at Station #1. It simultaneously recorded both surface water temperature and air temperature, one meter above the water, so as to define the boundary layer temperature gradient and its variation with the radiation balance.
- b) Due to the alder growth at Site 2, the wind speeds recorded were very low. Hence, we added another wind run recorder which was placed at a height of 6 meters, about 3 meters above the tree top level.
- c) Specific temperature measurements were made to determine the vertical temperature gradient over the fjord. Two systems were used for this. A 10 meter pole was mounted on a raft so that a ventilated

thermistor could be raised and lowered by means of a rope and pulley. Readings were taken at 1, 2, 4, 7 and 10 meters above the water surface. The other system used helium filled balloons to raise a thermistor. Temperatures were measured in this manner at about 10 meter intervals from sea level up to a maximum height of 250 meters. The profiles were measured under different sky conditions and at different times of the day.

The field work started on 10 June and finished on 9 September 1977.

RESULTS

Air Temperature

The most important parameters for air pollution potential are wind speed and the frequency, strength and persistence of temperature inversions. To obtain some knowledge concerning these parameters, the two sites with an altitude difference of 127 meters were established, one near sea level (Goose Cove), and the second on top of an adjacent hill (Alder site). Some difficulties with the calibration and the thermograph made data obtained after 1 August 1976 somewhat dubious and, hence, for calculating the strength of inversions only the period of 13 June to 21 July was used.

Temperature inversions were found on about one-third of all days for at least part of the day. They were most frequent during early morning and when skies were clear. This is understandable as at such times the radiation balance is negative and the surface is cooled.

In Figure 2 the mean daily temperature variation is given for:

- (a) clear sky,
- (b) scattered clouds and
- (c) broken or overcast skies

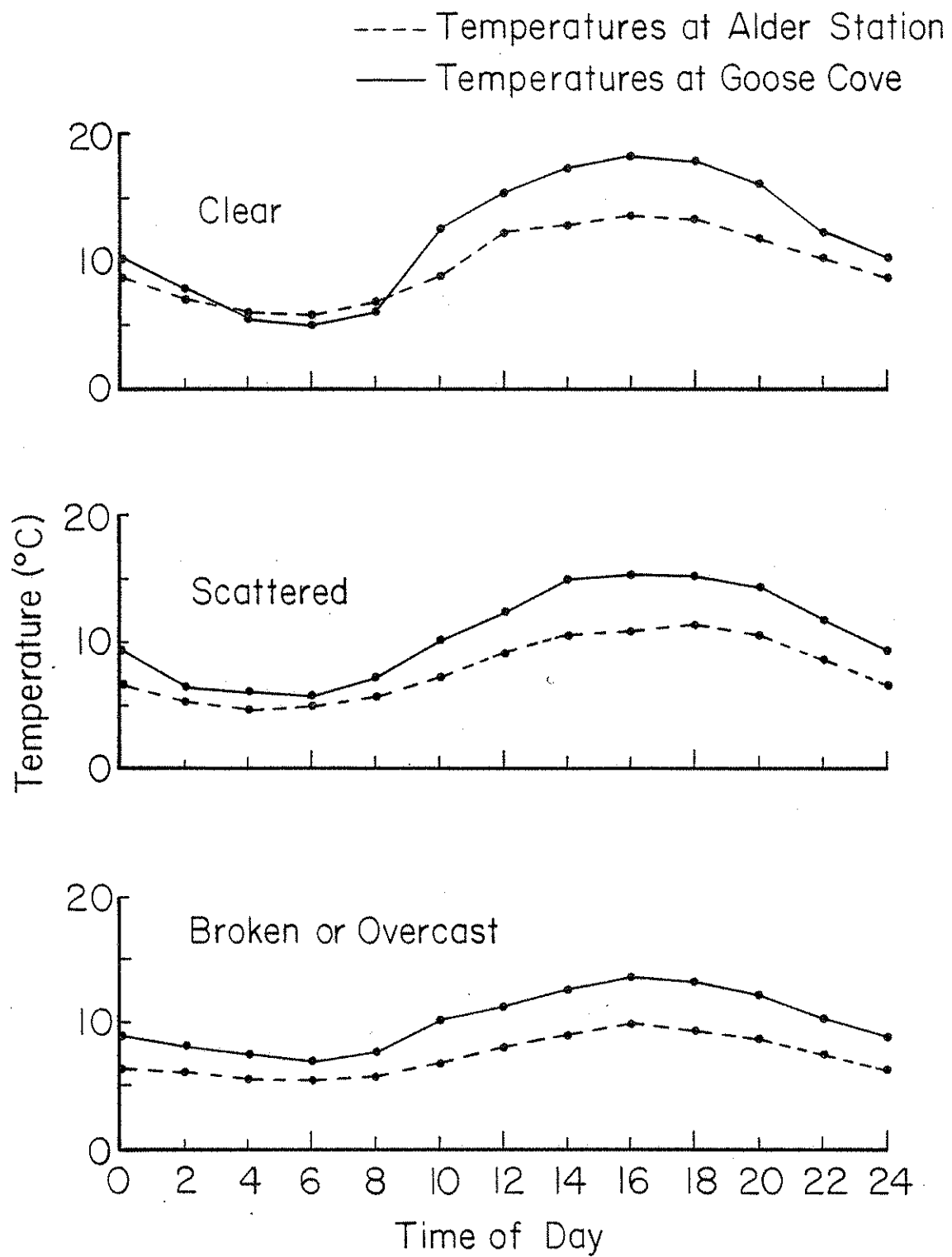


Fig. 2 Diurnal variations in the inversion strength as function of cloudiness for summer 1976.

The amount of cloudiness was estimated from the pyrlieliograph trace.

In general, Figure 2 shows inversions only during the early morning hours (from 3:00 to 8:30 a.m.). Eighty-three percent of the days with clear skies showed an inversion for at least part of the day. When scattered clouds were present, no inversions were observed in the mean values plotted in Figure 2, but on 29% of such days temperature increased with height during at least one observation per day. During overcast or broken sky conditions, inversions occurred only 16% of the time, which again does not show up in the mean values plotted in Figure 2.

For the whole period, the temperature at the upper station averaged 2.8°C lower than at the sea level station; this gives a lapse rate of -2.2°C per 100 m which is far in excess of the adiabatic rate. The anomalously high value is attributed to the specific microclimate of the lower station which was located about 20 meters away from the water and was protected by brush. During daytime when solar radiation was received, a higher temperature was observed at this site than it would have been at the same height over water. This phenomenon was verified during the second year of observations.

From 23 July to 8 September 1977, we had temperature records from the raft, as well as from the hill station. The air temperature over the raft (1 meter height) is a better representation of the temperature over the fjord; even so, some overheating might occur due to the wooden platform on the raft during periods with sunshine. Nevertheless, the upper station averaged 0.53°C lower than the sea level station; this gives a lapse rate of $-0.42^{\circ}\text{C}/100$ meters, substantially less than measured during the previous summer.

Spot measurements were carried out to obtain more detailed information of the temperature profile. The values found in the lowest 10 meters are shown in Figure 3. Measurements were made at altitudes of 1, 2, 4, 7, and 10 m above the raft around the clock at 2 or 4 hourly intervals for overcast skies and for scattered cloud conditions. Clear skies were not experienced during the time these round the clock measurements were made. For overcast and broken cloud conditions the temperature at 1 meter was cooler by 1.2°C or 2.0°C , respectively, than at 10 meters. The profile follows fairly closely a logarithmic profile. The increased inversion strength during times with less clouds was expected, and should become more extreme in clear weather. In general this thermal layering means, of course, that the air is very stable in the lowest 10 meters.

To extend the measurements to greater altitudes, balloon ascents were carried out during the summer of 1977. These data are believed to be of special relevance as such measurements cover the layer in which cruise ship exhaust is emitted. In total eleven balloon ascents were made; five under overcast skies (Figure 4), and six under clear skies (Figure 5). Only three of the ascents, all on overcast days, were made directly over the water in mid-inlet. The other eight were made from the beach in Goose Cove and may show local warming up to 20 or 50 meters.

Some features of these soundings deserve special comment. On 22 July 1977, ascents were made at 1730 and 2200 hours from the beach. Temperatures over the beach were isothermal at 1700 hours but at 2200 hours an inversion of 2.4°C was present in the lowest 120 meters. Above 120 m the temperature decreased at the adiabatic rate. Temperature profile measurements above the mid-inlet carried out on 26 August 1977, again under overcast skies, showed inversions in all cases. The mid-inlet

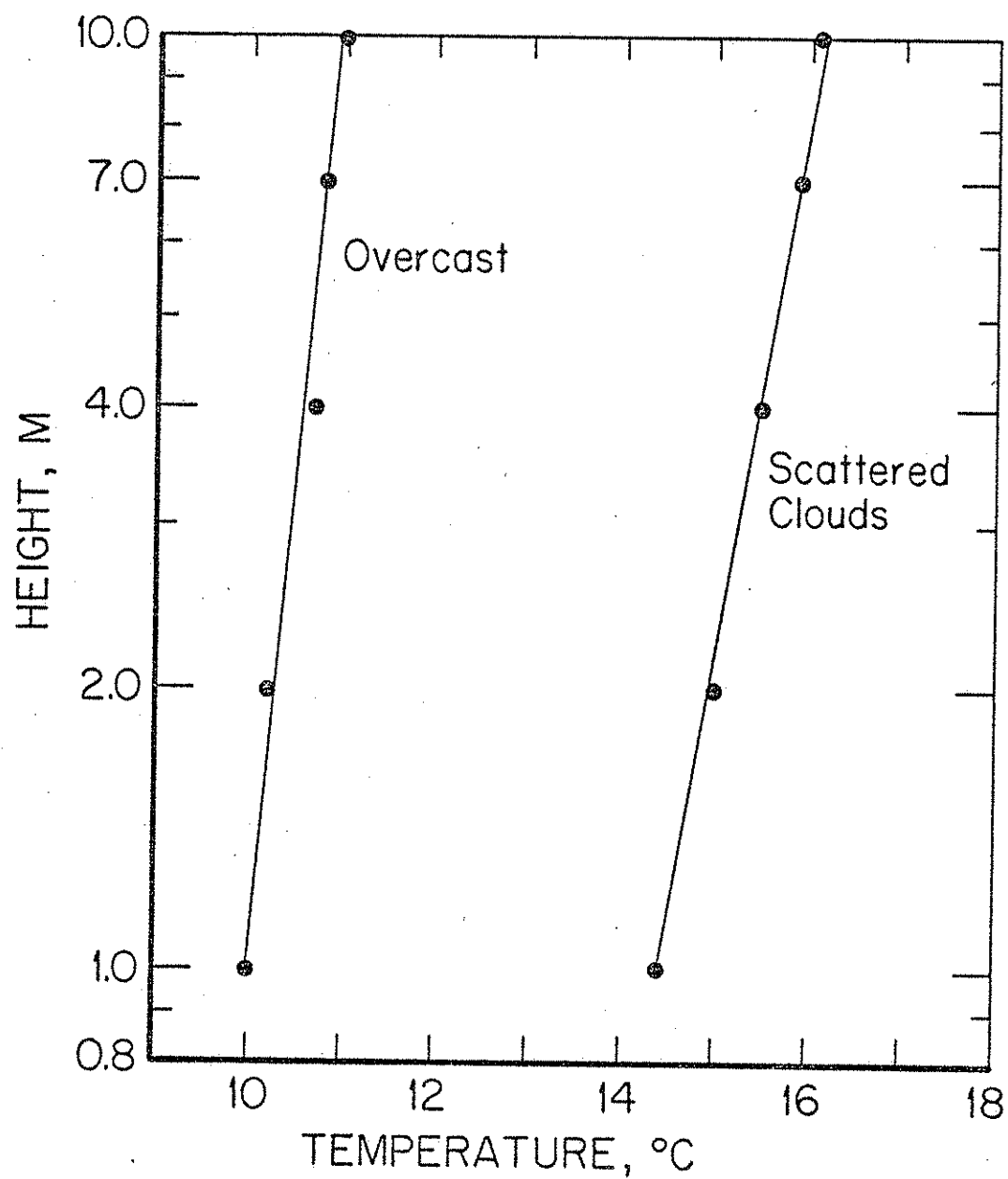


Figure 3. Air temperature plotted against logarithm of altitude in the first 10 m above the surface during July and August 1977.

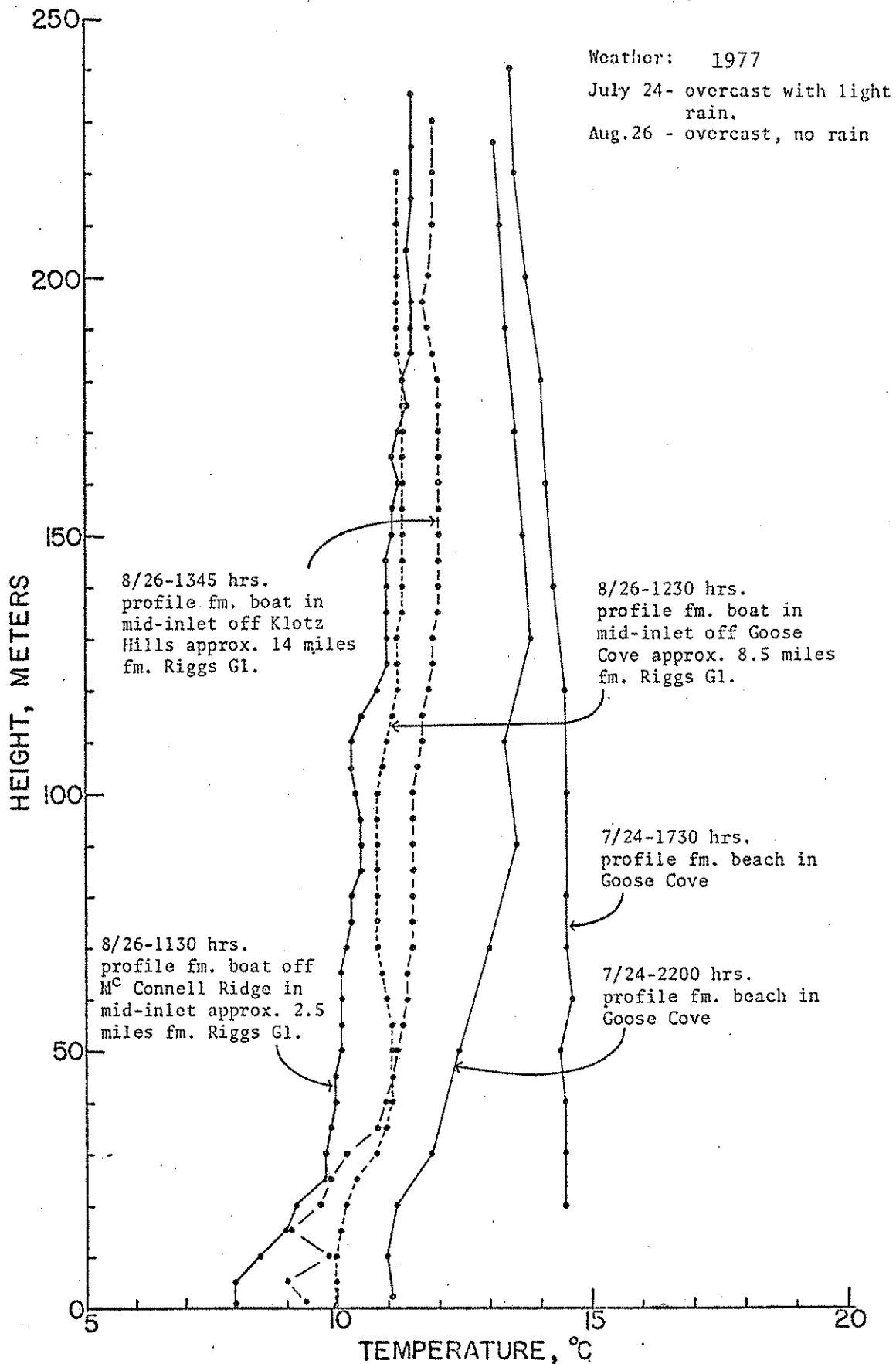


Figure 4. A plot of the vertical temperature profiles during overcast conditions made by balloon ascents of a thermistor. Measurements are sequential with as much as one-half hour between the beginning and the end of a single profile. Error is $\pm 0.5^{\circ}\text{C}$ and ± 5 meters.

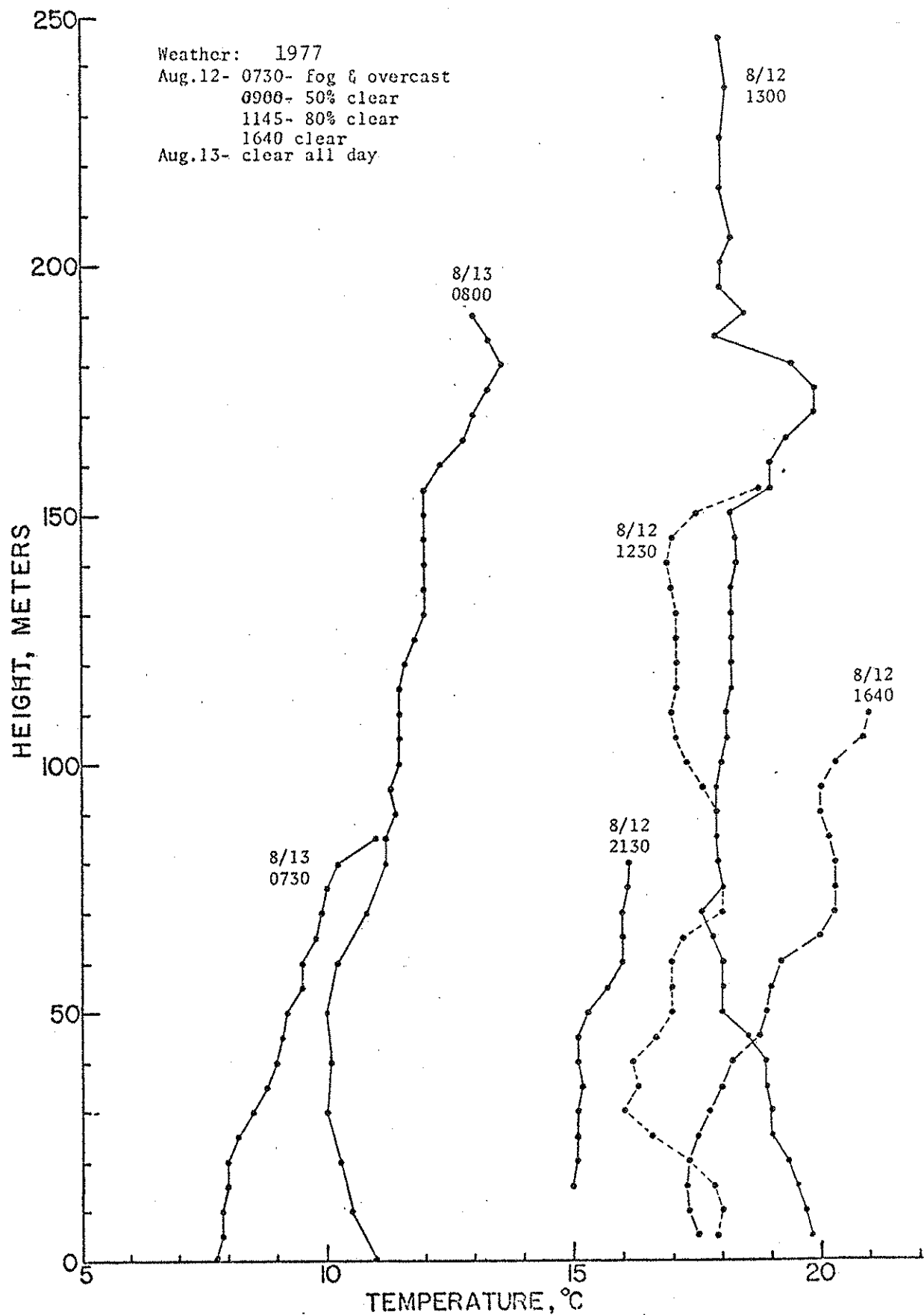


Figure 5. A plot of the vertical temperature profiles during clear sky conditions made by a thermistor. Measurements are sequential with as much as one-half hour between the beginning and the end of a single profile. Error is $\pm 0.5^{\circ}\text{C}$ and ± 5 meters.

inversion was especially strong in the ascent made about 4 kilometers off McConnell Ridge (Figure 4); this is probably caused by the proximity of the glacier.

Under clear skies the thermal structure is more complex and changes rapidly on time scales as short as 30 minutes. Consider a combination of the profile at 0730 hours on 13 August 1977 with the upper half of the 0800 profile on the same day (Figure 5). The bottom half of the 0800 profile has begun to show the influence of the morning sun. However, the combined profiles indicate an inversion of about 2.5°C for the first 100 meters of the atmosphere. This value might be typical of the early morning before direct sunlight reaches into the inlet. The inversion might have somewhat higher values earlier, but we did not measure any temperature profiles at that time. By midday under clear sky conditions, the stable morning air near the surface at our beach site was replaced by a 40-50 meter thick, unstable layer (see ascents of 1230 hours and 1300 hours). However, such unstable layers are not expected above the water away from shore in the fjord. Overlying the lowest 40-50 meter layer was an isothermal layer. In the afternoon (see ascents of 1640 hours) the air above the beach was stable again. At 2130 hours of the same day stable conditions were found again, but the strength of the inversion was diminished somewhat from the afternoon value. We don't know the reason for this, but expect it is due to wind action.

Wind

The wind speeds measured in 1976 are given in Table 2. The values were very low; no monthly mean exceeded 6 mph. The hill station showed lower wind speeds than the valley station. This could be a katabatic

wind effect, but the growth at the hill station was relatively high, and the 1976 anemometer, with a height of 3 meters above ground hardly penetrated the tops of the brush. Hence, a second anemometer was installed in 1977, it extended about 3 meters above the top of the brush (6 meters above ground). When comparing the 1977 values, from the top and bottom sites, an increase of wind speed with altitude was found (Table 2), as was expected. The average of this increase was 24%. Wind speeds were light during both summers, and when comparing data from 1976 with those from 1977, good agreement was found; the summer averages at Goose Cove were 4.9 and 4.7 mph, respectively. Both summer winds were slightly above average in July and August and slightly weaker in June and particularly in September.

In both summers winds blow mostly down the fjord. In Figures 6 and 7, the wind direction distribution is given in graphical form on a monthly basis. These gentle northerly winds, which flow steadily down the fjord, might be caused by the katabatic winds, which are commonly found on glaciers (e.g. Streten and Wendler, 1963, Streten, et al., 1974). Three large glaciers, Muir, Riggs, and McBride in the upper regions of Muir Inlet provide a large drainage area for such winds; after reaching the fjord bottom, the air is forced to continue moving slowly down the fjord. Owing to the high mountains surrounding Muir Inlet (Figure 1), the area is otherwise fairly sheltered from cyclonic disturbances.

A comparison of wind speed, both the averages and the fastest mile, shows the winds to be higher in Juneau than at the Alder Station. This holds true for both years (Table 3). In Juneau, which is more exposed to the general circulation, easterly winds with a small southerly component were observed; at the Alder Station the winds were consistently from the North, i.e., down the fjord.

Table 2
Wind Speed (in mph) of Two Sites in
Glacier Bay National Monument,
Summer 1976 and 1977

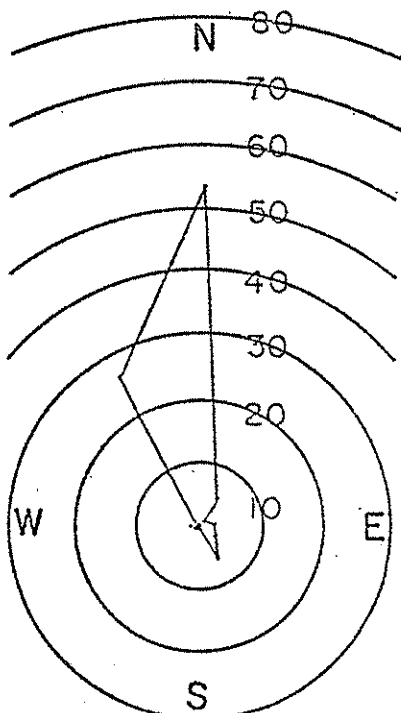
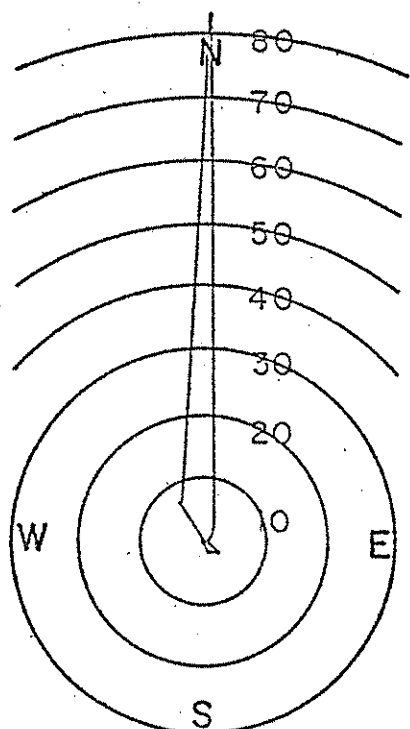
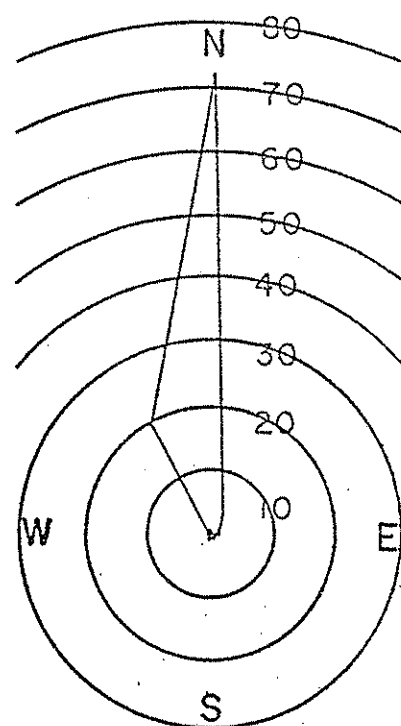
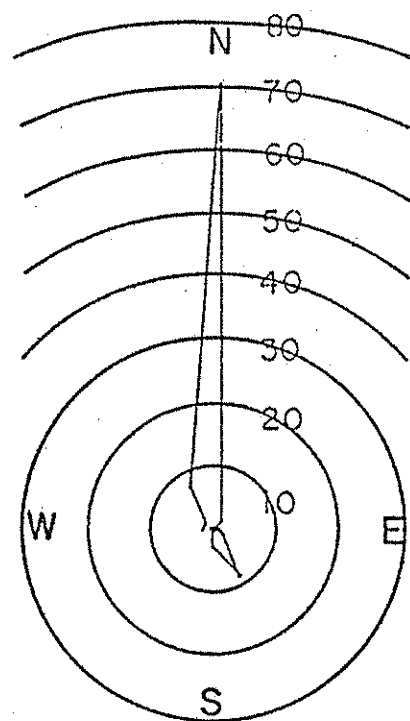
	June 18 days 13-30	July 28 days 1-16, 20-30	August 19 days 1-16, 25, 26, 30	September 12 days 31 Aug-11 Sept
1976				
Alder Site a)	3.7	4.8	4.4	3.1
Goose Cove c)	4.1	5.2	5.0	3.9
1977				
	June 21 days 11-30	July 31 days 1-31	August 28 days 1-27	September 9 days 1-9
Alder Site a)	4.3	4.6	4.7	3.4
b)	5.9	6.3	6.4	4.7
Goose Cove c)	4.7	5.1	5.2	3.7

a) at brush height
b) about 3 m above brush height
c) about 3 m above ground

Table 3

A Comparison of Wind Velocity (mph) of a Site in Glacier Bay
National Monument and Juneau Airport for Summers 1976 and 1977.

		June 18 days 13-30	July 28 days 10-16, 20-30	August 23 days 1-19, 25, 26, 30, 31	September 11 days 1-11
Glacier Bay National Monument (Alder Site)					
	Wind Speed Resultant	3.7	4.8	4.2	3.0
1976	Direction	350°-N	350°-N	350°-N	350°-N
	Fastest Mile	10	12	11	8
	Direction	350°	350°	330°	160°
Juneau Airport					
	Wind Speed Resultant	6.9	8.5	7.4	7.2
1976	Direction	105°	100°	100°	100°
	Fastest Mile	21	28	24	31
	Direction	120°	120°	120°	120°
		June 20 days 10-30	July 31 days 1-31	August 31 days 1-27	September 9 days 1-9
Glacier Bay National Monument (Alder Site)					
	Wind Speed Resultant	4.3	4.6	4.7	3.4
1977	Direction	XXX	XXX	XXX	XXX
	Fastest Mile	9.3	9.3	9.9	9.3
	Direction	360°	360°	360°	360°
Juneau Airport					
	Wind Speed Resultant	7.3	6.8	5.9	9.7
1977	Direction	33°	80°	10°	8°
	Fastest Mile	21	20	21	21
	Direction	125°	150°	120°	120°



July

Sept

Figure 6. The wind direction distribution for the high altitude, 127 m (Alder site) at Goose Cove, Glacier Bay National Monument, Summer 1976.

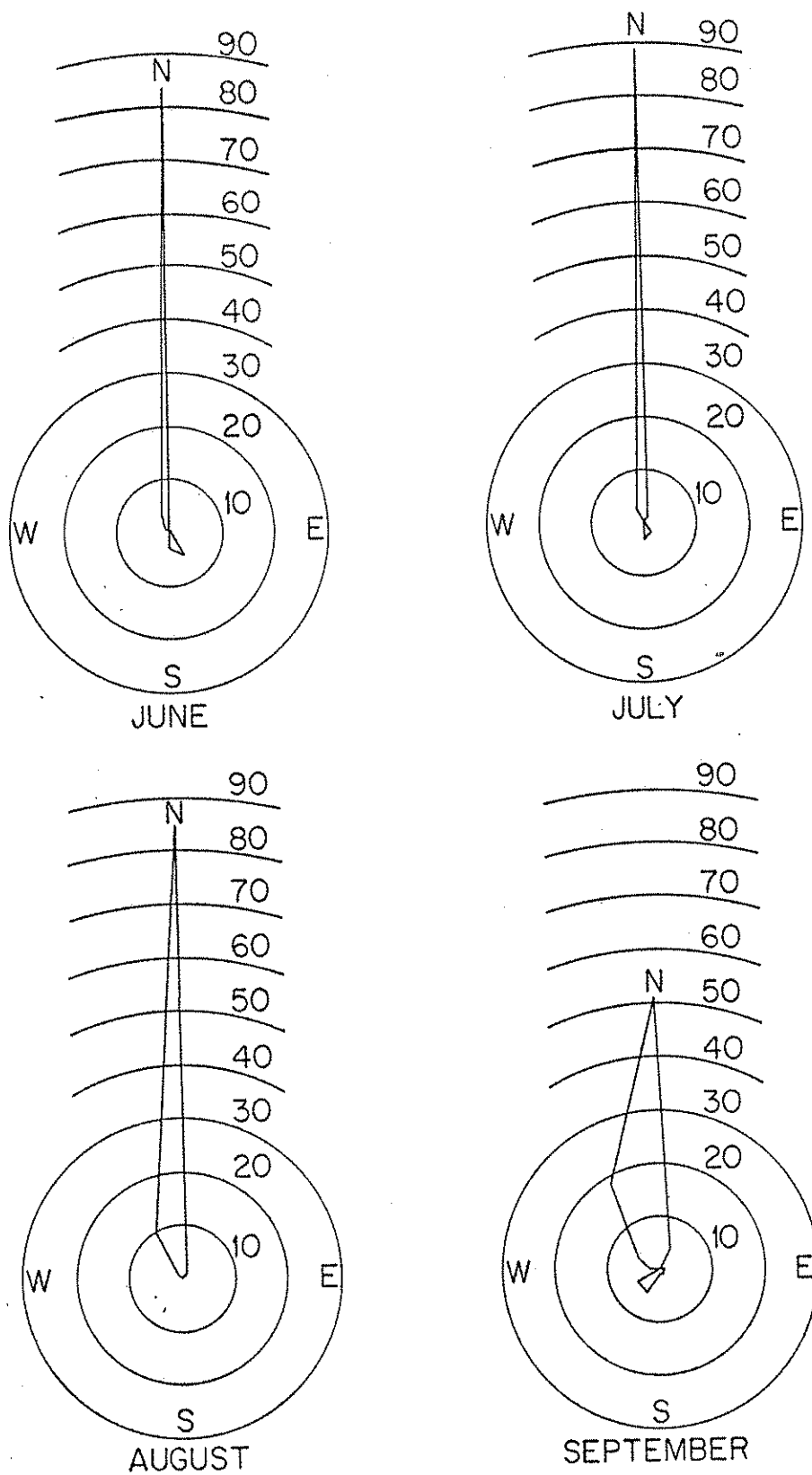


Figure 7. The wind direction distribution for the high altitude, 127 m. Alder Site at Goose Cove, Glacier Bay National Monument, Summer 1976.

The low wind speeds and the apparent control by glacier katabatic winds in the upper fjord region are significant from the air pollution point of view. It implies a minimum of mechanical mixing in the air mass, which permits pollutants to accumulate.

Nuclei Counts

The nuclei count gives some information on the amount of pollutants in the air. During the summer of 1976 (1 June to 6 September), 44 measurements were made. Sequences of several readings before and after ship passages in the bay were taken with the following results (nuclei per cm³):

Total range of "background" values	5 - 30	} x 10 ³
Total range of values	5 - 70	
Incremental increase in value when ships pass	10 - 40	

These data can be compared with values found in the literature by citing some values given by Mason, B. J. (1957), The Physics of Clouds (Table 2.4, p. 42), Oxford University Press, London.

Nuclei Content of the Atmosphere in Different Types of Localities (After Landsberg)

Locality	No. of Places	No. of Observations	Average Concentrations
City	29	2,500	147,000
Town	15	4,700	34,300
Country inland	25	3,500	9,500
Country seashore	21	2,700	9,500
Mountain:			
500-1000 m	13	870	6,000
1000-2000 m	16	1,000	2,130
2000 m	25	190	950
Islands	7	480	9,200
Ocean	21	600	940

It may be of more direct Alaskan interest to compare them with Alaska's most famous air pollution center, namely Fairbanks and its surroundings (Benson, 1970; Ohtake, 1970; Bowling and Benson, 1978).

The following data are from Ohtake (1970, p. 27, Table 3).

Fairbanks, downtown	100 to 6000	} x 10 ³
University of Alaska	20 to 60	
Ester Dome	0.5	

The values found in Glacier Bay National Monument are relatively high, exceeding those found at the University of Alaska near Fairbanks and approaching values observed in downtown Fairbanks itself.

The more visible effects of ship traffic are apparent in Figures 8, 9, and 10 which show smoke lying above the water surface in the fjords of Glacier Bay National Monument.

Water Temperature

Water temperatures vary substantially as one moves along the length of the fjord. This is shown in Table 4 and Figure 11. Generally, it can be stated that the nearer one gets to the glacier, the colder it gets, e.g. the water was -1.0°C just off McBride Glacier and is probably below 0.0°C in the entire area north of McConnell Ridge, due to both the large amount of ice in the water, and large quantities of cold melt water runoff from the glaciers. Inlet temperatures warm to about 5.0°C off Goose Cove and on up to 9.0°C at the entrance from Glacier Bay to Muir Inlet. This distribution confirms that found in July 1967 by Matthews and Quinlan (1975). The large differences between the temperature profile of June 27 and July 7 (Table 4) are probably due to the measurements being made during different parts of the tidal cycle.

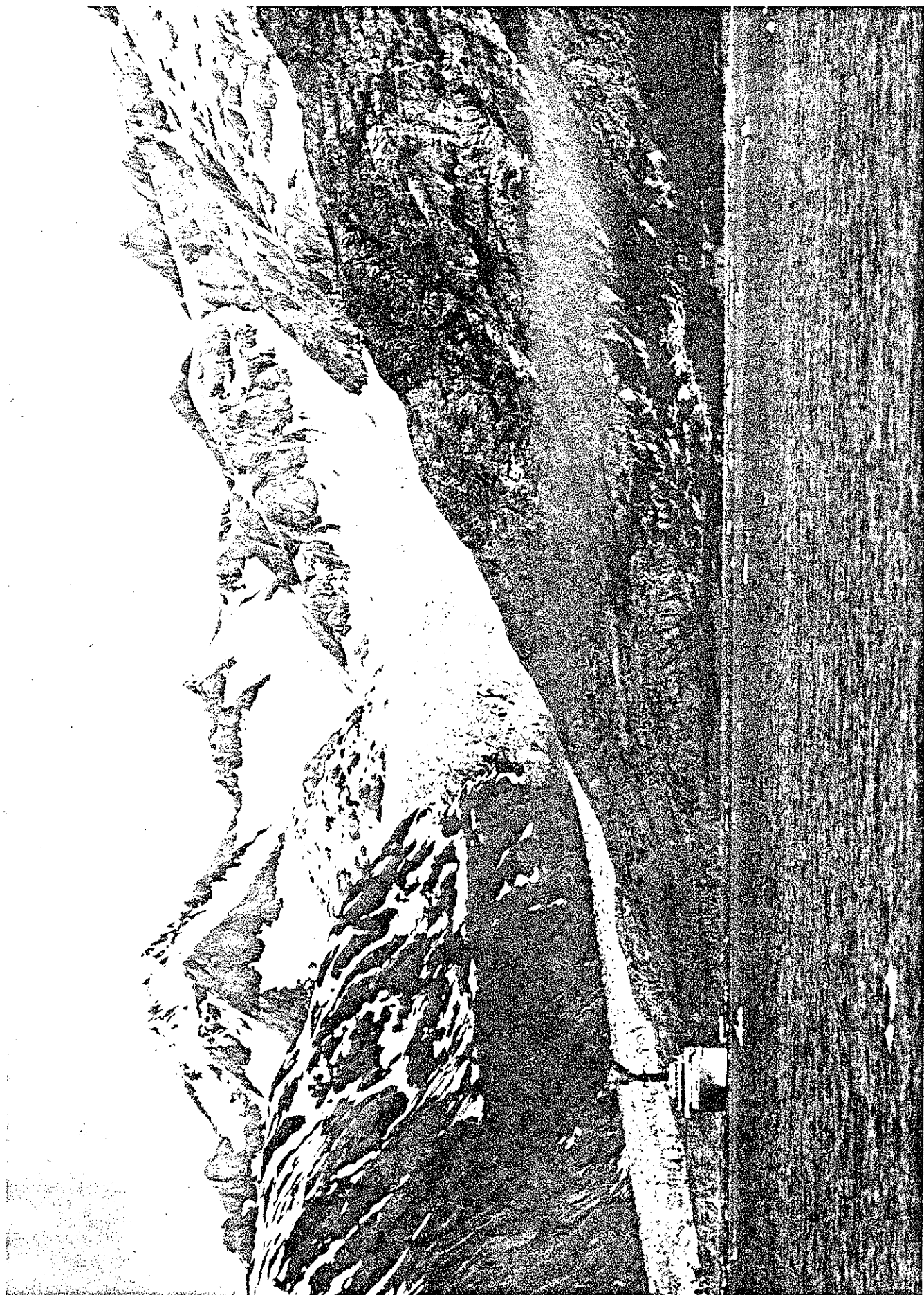


Figure 8. Photo of Cunard Adventurer Invader in Muir Inlet.

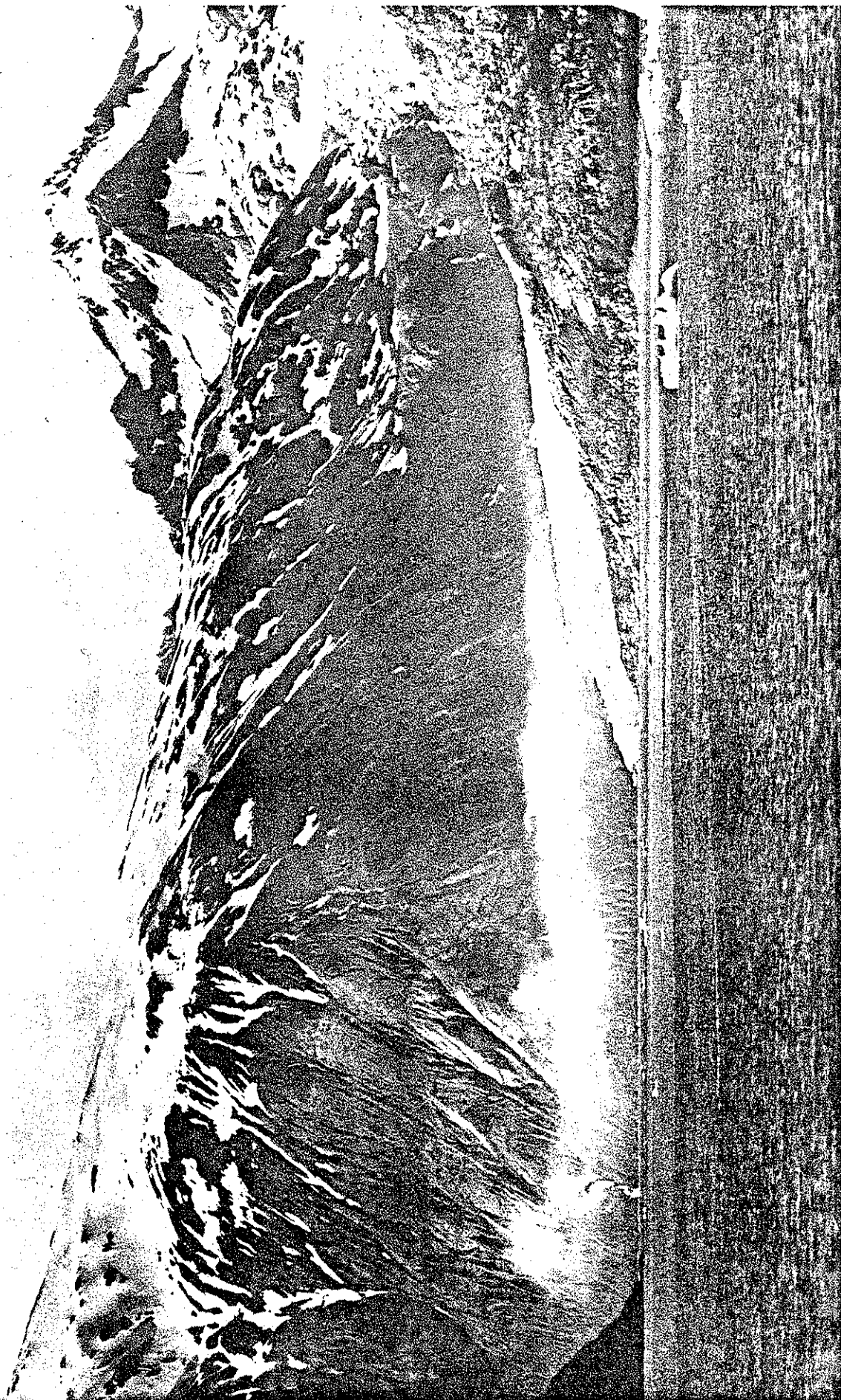


Figure 9. Princess Ship at Riggs Glacier, Glacier Bay, Summer 1976.
(Photo by M. Nigro)

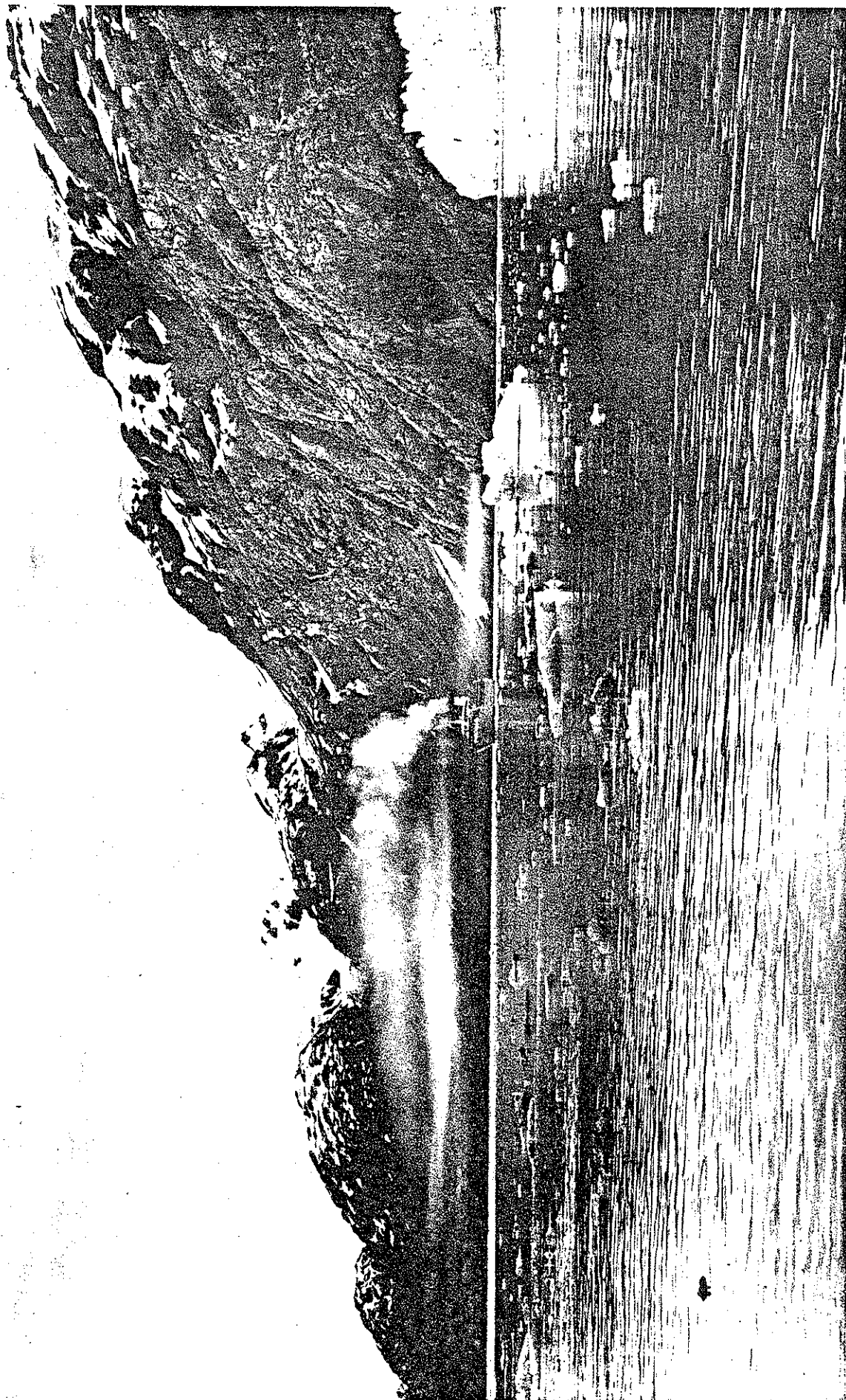


Figure 10. Sun Princess at Margerie Glacier, Tarr Inlet, Glacier Bay,
Summer 1976. (Photo by M. Nigro)

TABLE 4-

Surface Water Temperatures
In Degrees Centigrade

<u>Date</u>	<u>Time</u>	<u>Location</u>	<u>Number</u>	<u>°C</u>
6/27/77	1415	North Marble Island	1	11.5
6/27/77	1445	Sturgess Island	2	10.0
6/27/77	1500	Garforth	3	9.0
6/27/77	1530	Klotz Hills	4	7.5
6/27/77	1600	Forest Creek	5	6.5
6/27/77	1610	Goose Creek	6	5.0
6/27/77	1615	Goose Cove	7	5.0
7/7/77	1615	North Marble Island	1	8.0
7/7/77	1645	Sturgess Island	2	9.0
7/7/77	1700	Garforth	3	8.0
7/7/77	1715	Klotz Hills	4	8.0
7/7/77	1730	Forest Creek	5	9.0
7/7/77	1745	Goose Creek	6	5.5
7/24/77	1030	Goose Cove Raft	7	4.7
7/24/77	1100	Off Wolf Point	8	2.3
7/24/77	?	500 M. from McBride Glacier	9	-1.5
7/24/77	?	500 M. from McBride Glacier	9	-1.0
7/24/77	?	500 M. from McBride Glacier	9	-0.5
7/24/77	?	in front of McBride Glacier	10	-1.0

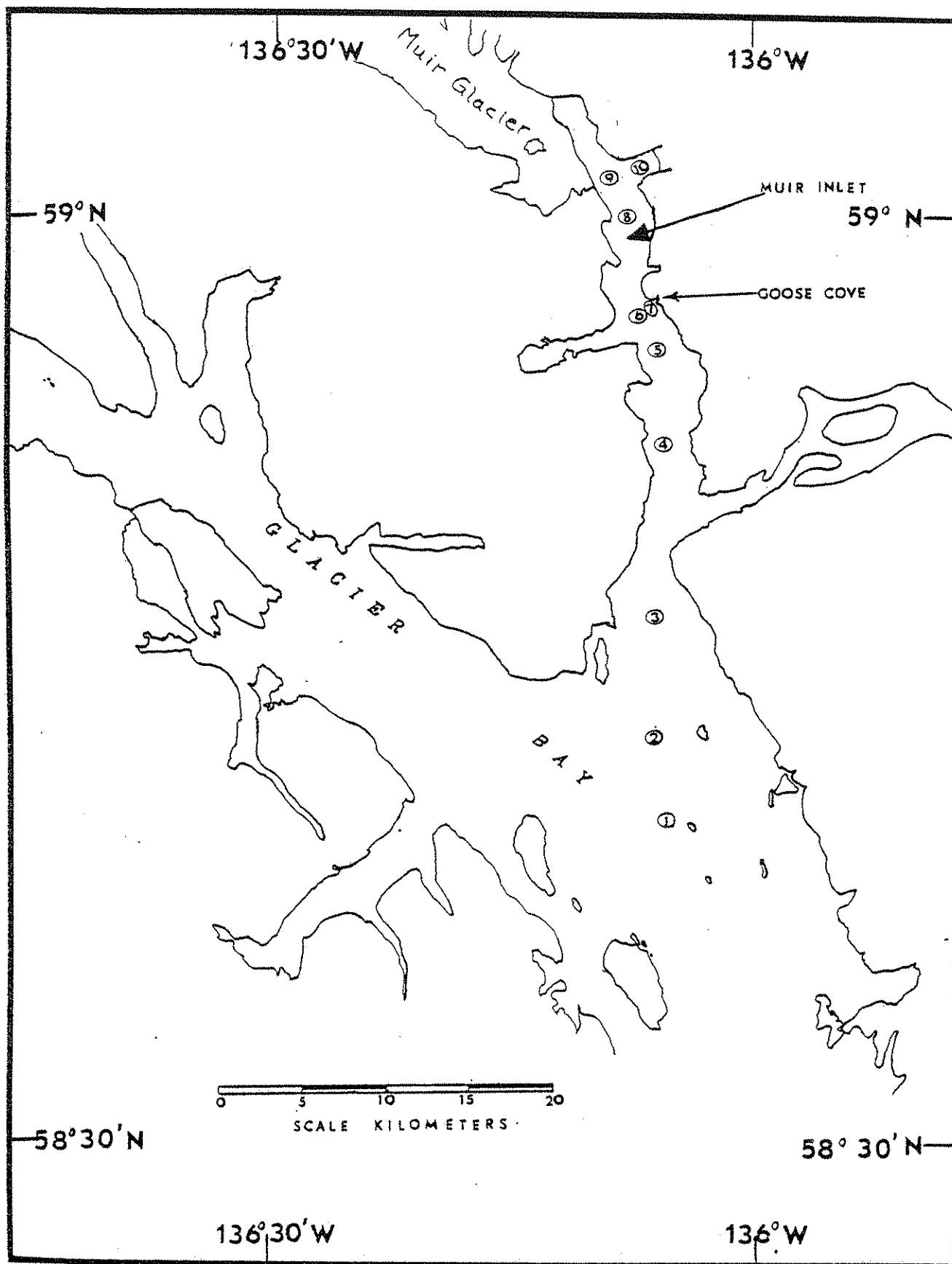


Figure 11. Map of Muir Inlet with Water Temperature Sites.

During the summer of 1977, a mean temperature of 4.5°C was found in the surface water at Goose Cove with a total range of 2.5 to 7.0°C. Typical daily variations were on the order of 1 to 2°C. Air temperatures in Goose Cove measured one meter above the water varied considerably depending on the radiation (Figure 12), but for the entire summer, until the very end of August, the air was always warmer than the water. The water, therefore, acts as a steady heat sink. It continually cools the overlying air without being warmed appreciably. This is especially true in the upper parts of the fjords where a large amount of latent heat is required to melt floating ice. The pyrheliometer chart (Figure 13), was used to determine the amount of cloudiness.

During overcast weather the one meter air temperature was about 4.5°C higher than the water temperature and varied little with the time of day. The cloud cover reduces the diurnal temperature variation of the air temperature by acting as a partial barrier to both daytime incoming radiation and nighttime outgoing radiation.

Under clear skies the one meter air temperature ran up to 12°C higher than the water temperature in mid-afternoon and down to just 0.5°C higher than the water in early morning. Hence, the effects of both radiative heating during the day and radiative cooling at night are maximized yielding large daily fluctuations of air temperature despite the constancy of water temperatures.

CONCLUSIONS

Any given environment's tolerance for pollution can best be defined by the speed with which it is able to disperse pollutants to acceptable background levels. Pollutants put into the air are normally dispersed in two ways:

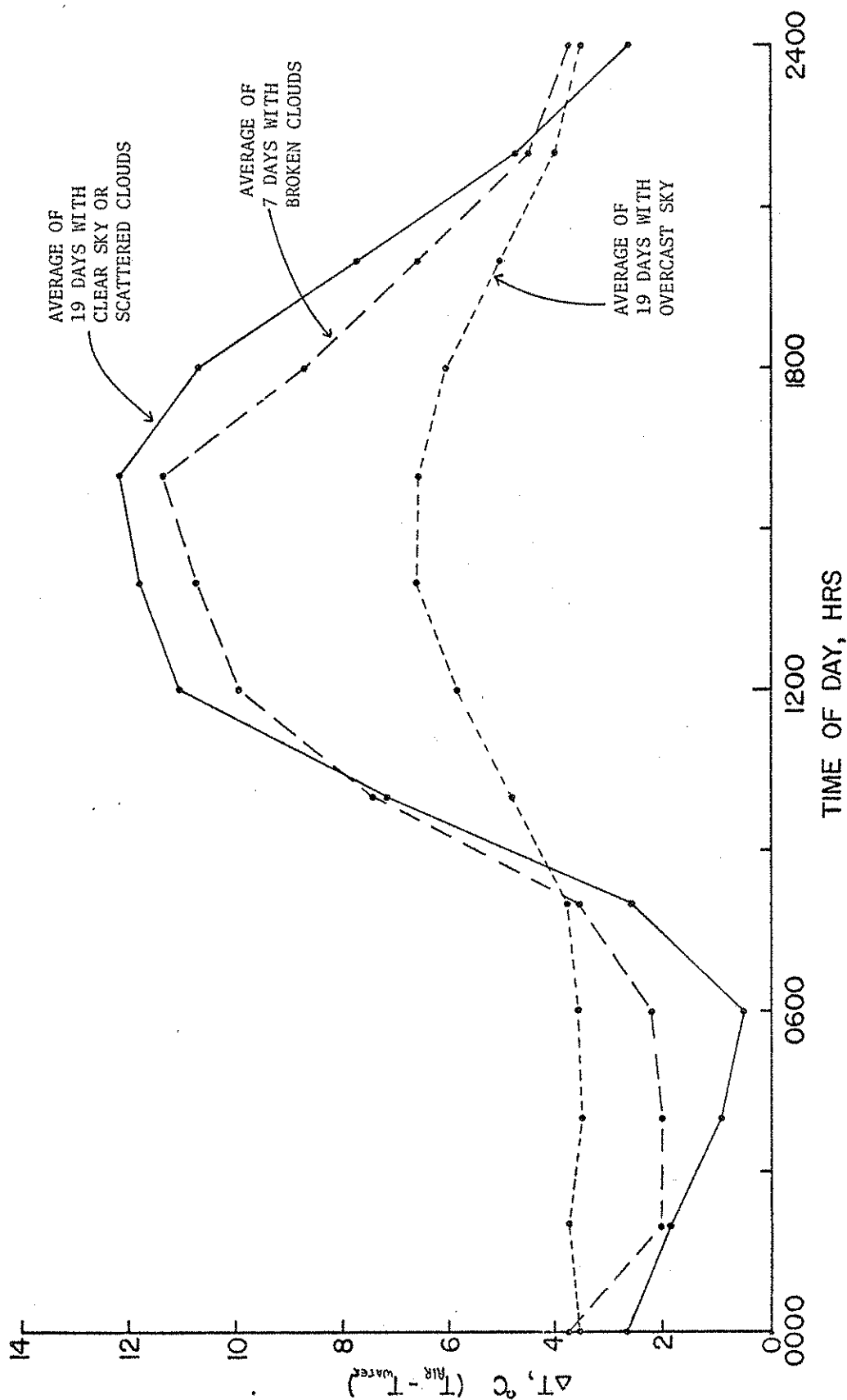
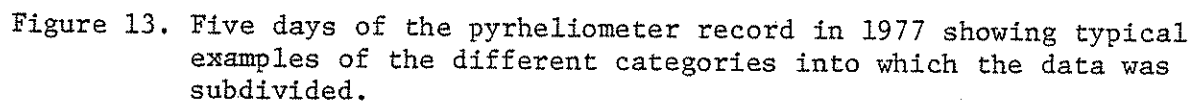


Figure 12. A plot of the difference in temperature between the air and water as a function of the time of day and the sky cover. The data is taken from temperature values every two hours that were read off the twin channel thermograph located on the raft in Goose Cove. The error is $\pm 1.0^\circ\text{C}$.



- a) by thermal convection of an unstable air mass, and
- b) by forced convection (mechanical mixing) produced by wind.

In Glacier Bay the low energy level of these two types of atmospheric mixing indicates an overall low tolerance for air pollution.

Air temperatures measured over the Inlet indicated that the air was almost always stable in the lowest 100 meters; this is mainly the result of surface cooling from the ice and cold water in the inlet. Only twice on one day, out of eleven profiles measured on four days, did we find normal temperature gradients and then only above 120 meters. Although statistical information on the strength and persistence of inversions is lacking it is clear that inversions are frequent if not continuous. Therefore thermal mixing is prevented much of the time.

In summary, the environment of upper Muir Inlet has a very low tolerance for air pollution due to limited atmospheric mixing. Probably the one mitigating factor is the prevailing unidirectional wind which carries the haze layers produced by cruise ship exhaust down the inlet and as the inlet opens up the haze gradually disperses.

RECOMMENDATIONS

One of our goals was to determine whether or not a more intensive study is required. Our present study clearly shows a low tolerance for air pollution in the fjords of Glacier Bay because of low wind speeds and persistent inversions. The conditions are intensified in the upper reaches of the fjords because water temperature remains lowest there. It is also clear that conditions within the fjords differ appreciably from conditions at the nearest meteorological stations (at Gustavus and Juneau).

Although we know there is a problem there is clearly a need for more information. At this time we see a need: (1) for basic meteorological data on a long-term basis in the fjords, (2) for specific monitoring of pollution levels, and (3) for detailed micrometeorological studies of selected areas.

The three needs can be met with different levels of sophistication and expenditure.

Some suggestions for each of the components are offered here in outline form. Detailed Planning for each component will be required to decide on priorities, sites of measurement, parameters to be measured, choices of equipment, and methods of handling data and processing it into a useful format.

Basic Meteorological Data

There are two ways to obtain pertinent data at the remote sites, which have no source of electric power, in the fjords of Glacier Bay, as well at the coastal site in Lityua Bay.

(a) Satellite Data Collection Platform (DCP): The use of a DCP to obtain data on air temperature, wind speed and direction, radiation, humidity, water temperature, etc., at such remote sites has been pioneered by the U.S. Weather Bureau, U.S.G.S. and BLM. We also have experience with such units and recommend that they be considered in the Glacier Bay National Monument. There are several types of DCP used with the several orbiting satellites. Our experience is with the GOES satellite and we have one available DCP designed for this satellite (I.D. No. 16 C 3 C 43 C Channel 77 GOES). We recommend the use of three DCP's in Glacier Bay,

two in the fjords and one at Lituya Bay. This program should probably begin with a single DCP to test its applicability in practice - this must include an adequate plan for handling data.

(b) Thermographs and Other Field Instruments: Hygrothermographs and anemometers and similar instruments for water temperature with spring-driven or battery-driven clocks are available which allow reliable records to be obtained at relatively low cost from remote stations. We have used such equipment in this study to obtain data over a span of a week or a month. Chart speeds are available for which allow one to record data for time spans as short as 6 hours or as long as 861 hours (35.9 days).

The use of these instruments would add to our understanding of air flow, and air and water temperature, in the Glacier Bay National Monument at lower cost than any other approach. However, the use of these instruments would be only possible when Rangers can visit the sites on weekly or monthly schedules to change charts.

Pollution Monitoring

Equipment for monitoring total pollutants and specific gases has been developed over the past few years which may be adaptable to remote sites in Glacier Bay. Continuous monitoring of some pollutants at two selected sites along a fjord should be considered for base line data and to observe changes produced by specific events.

Micrometeorological Studies

In regions, such as the upper part of Muir Inlet, where the pollution potentials seem highest it would be useful to carry out detailed studies. These should include measurement of air temperature and wind profiles

together with careful monitoring of the dispersal of pollutants from passing ships. Pollution levels measured before, during, and after passage of the ships would be correlated with the prevailing micro- and meso-scale meteorological conditions. This type of study should be done during both clear and cloudy weather. It will yield useful information about the entire interacting system of fjord and cruise ships.

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