How to Use Radiofacsimile Weather Maps

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PREFACE

The purpose of this booklet is to show techniques that can be applied to effectively use radiofacsimile weather maps at sea and to give the basic information needed to understand the development of waves and the weather. The booklet is supplemented with a separate pamphlet containing sample maps and the latest broadcast schedules for radiofacsimile stations in the U.S. and Canada.

SECTION I

HOW TO USE RADIOFACSIMILE WEATHER MAPS

I. INTRODUCTION

It was once remarked by Benjamin Franklin that "some men are weatherwise, but most are otherwise", which was certainly true back in his day because it was impossible to get an understanding of the weather patterns from the few stations that made observations. Folklore methods handed down from ancient times were about the only methods used by sailors to forecast the coming weather. Most of us have found the old maxim "rainbow at night, sailor's delight; rainbow in the morn', sailors take warn'" to be occasionally true, but it fails us more often than not. Having a radiofacsimile recorder aboard your vessel clearly gives you advantages far beyond any of the folklore sayings or just trusting to plain luck. It is the purpose of this publication to show you what weather charts you actually need to help you track this weather, how to interpret them, and finally, how to make judgements about future weather and sea conditions.

A very large number of different types of radiofacsimile charts are broadcast by various organizations throughout the world, but we use as examples those produced by the United States and Canada for the North Pacific Ocean. The principles learned in this publication can be applied to weather charts put out by any nation due to standards set forth by the World Meteorological Organization and adopted by all nations. By the time you finish this booklet, you should not only be able to keep track of the weather, but also be able to anticipate what changes will occur. It will be essential to become familiar with the symbols used on weather maps to represent wind speed and direction (see symbol figs.) before you read Section II if you have not used weather maps before.

The broadcasting of actual weather maps to ships at sea by civilian organizations is a relatively new innovation that was begun in the U.S. in 1971 by the National Weather Service with the cooperation of the U.S. Coast Guard (USCG). (However, weather maps have been drawn in this country on a regular basis since 1870, though initially for only the eastern part of the nation.) As methods of communicating improved more and more observations could be collected at a central location and then used for producing maps that eventually covered the entire country. Forecasts were primitive by today's standards as they were only valid eight hours into the future. Improvements came rapidly for land areas, but lagged considerably for mariners because there was no way the seafarer could send observations from his vessel to meteorological offices ashore. This situation changed shortly before WWI when radiotelegraphy came into use, permitting real time observations to be sent to shore where they could be analyzed, and, in turn, forecasts could be sent back to the vessels at sea.

As the radio equipment improved over the years, so did the forecasts; however, the mariner was never able to get a detailed picture of the overall situation. Radiofacsimile changed all that. A few of the advantages of radiofacsimile are:

1. You can see the weather pattern almost at a glance and can follow most changes with ease.
2. You can use the maps to see some of the facts that were used by the meteorologist when he issued the marine forecast. (The latest marine forecast for your location should always be aboard, too.)
3. You can make a general weather prediction for your track or area up to 72 hours ahead.
4. You can often plan evasive action and avoid the worst of a storm before you are in it.
5. If a storm is unavoidable, you can get a good idea how long it will last.
6. Some of the sea surface temperature charts can be used to locate warm and cold patches of water where certain species of fish tend to congregate.

Naturally, you can think of other advantages for your particular situation, but the list shows that having actual maps aboard permits you to judge the situation much better than by relying on forecasts alone or just trusting to luck. To get the most out of the maps as possible, the important factors that affect the weather and the state of the sea need to be examined.

SECTION II

BASIC MARINE WEATHER

The four weather elements that affect operations at sea the most are wind, waves, fog, and superstructure icing. (In some areas sea ice is important.)

WIND

The strength of the wind is directly related to the difference in barometric pressure between two points. The surface weather map, which depicts the weather pattern next to the earth's surface, shows the pressure pattern through the use of isobars (pronounced "eye-so-bars"). Isobars are lines connecting points of equal sea level pressure, and the closer they are together, the stronger the wind will be. The barometric readings used to draw the isobars are collected from ships at sea and a large number of land stations along with a few readings from environmental weather buoys moored in the ocean. Corrections are applied to many of the readings to compensate for elevation and instrument error, which, in turn, permits isobars to be drawn on a common sea level reference plane. Centers of high pressure and low pressure can be determined as well as the shape of the general weather pattern.

The pressures found on weather maps are in millibars (mb or MB) instead of inches of mercury (the height of a column of mercury in an evacuated tube due to the weight of the air). Table I shows the conversion of millibars to inches of mercury for the range of pressures normally encountered at sea level.

TABLE I

Conversion of Millibars to Inches of Mercury

(1 mb = 0.02953 in. of mercury)

MB	INCHES	MB	INCHES	MB	INCHES	MB	INCHES
940	27.76	970	28.64	1000	29.53	1030	30.42
941	27.79	971	28.67	1001	29.56	1031	30.45
942	27.82	972	28.70	1002	29.59	1032	30.48
943	27.85	973	28.73	1003	29.62	1033	30.50
944	27.88	974	28.76	1004	29.65	1034	30.53
945	27.91	975	28.79	1005	29.68	1035	30.56
946	27.94	976	28.82	1006	29.71	1036	30.59
947	27.97	977	28.85	1007	29.74	1037	30.62
948	27.99	978	28.88	1008	29.77	1038	30.65
949	28.02	979	28.91	1009	29.80	1039	30.68
950	28.05	980	28.94	1010	29.83	1040	30.71
951	28.08	981	28.97	1011	29.86	1041	30.74
952	28.11	982	29.00	1012	29.88	1042	30.77
953	28.14	983	29.03	1013	29.91	1043	30.80
954	28.17	984	29.06	1014	29.94	1044	30.83
955	28.20	985	29.09	1015	29.97	1045	30.86
956	28.23	986	29.12	1016	30.00	1046	30.89
957	28.26	987	29.15	1017	30.03	1047	30.92
958	28.29	988	29.18	1018	30.06	1048	30.95
959	28.32	989	29.21	1019	30.09	1049	30.98
960	28.35	990	29.24	1020	30.12	1050	31.01
961	28.38	991	29.26	1021	30.15	1051	31.04
962	28.41	992	29.29	1022	30.18	1052	31.07
963	28.44	993	29.32	1023	30.21	1053	31.10
964	28.47	994	29.35	1024	30.24	1054	31.13
965	28.50	995	29.38	1025	30.27	1055	31.15
966	28.53	996	29.41	1026	30.30	1056	31.18
967	28.56	997	29.44	1027	30.33	1057	31.21
968	28.59	998	29.47	1028	30.36	1058	31.24
969	28.62	999	29.50	1029	30.39	1059	31.27

When viewed from space, the wind direction is clockwise around a high pressure center and counterclockwise around a low pressure center in the *Northern* Hemisphere. In the *Southern* Hemisphere, the winds are counterclockwise around a high and clockwise around a low. Over waters bounded by land masses, the wind tends to blow from higher pressure toward lower pressure in directions oriented by the terrain. Figure 1 shows some of the important features about the wind in lows and highs.

The isobars in the figure are labeled every four millibars with the 10 or 9 preceding the value omitted (e.g., 28 = 1028 mb, 24 = 1024 mb . . . 00 = 1000 mb, 96 = 996 mb, 92 = 992 mb, etc.). Winds usually blow at a 10° to 30° angle to the isobars toward lower pressure over the open ocean, but over the land, the wind direction is highly affected by the terrain.

Refer to line AB along latitude 50°N. Note that the isobars are evenly spaced (1° of latitude apart in this case), but that the winds increase from 35 knots near A to 50 knots near B. This is due to the fact that the isobars are more curved near the center of the low. The isobars would have to be much closer together at A to get the same strength of wind found at B.

Refer to boxed area enclosed by dashed lines. Straight isobars spaced closely together create high winds and seas.

Refer to line CD. The same effect on wind speed due to curvature of the isobars occurs as along line AB, but changes in wind speed due to changes in latitude also occur. Winds near D are 80 knots versus 50 knots nearer to C for the same 1° of latitude spacing between isobars and for the same curvature of the isobars. Thus, the lower the latitude, the stronger the winds will be, providing the isobaric spacing and curvature are equivalent to that found at higher latitudes. This relationship, for theoretical reasons beyond the scope of this booklet, begins to break down below about 15° to 20° of latitude and does not apply at all at the equator.

Refer to E. Winds blow easterly out of the bay due to higher pressure at the head of the bay than at its mouth. The terrain funnels the wind.

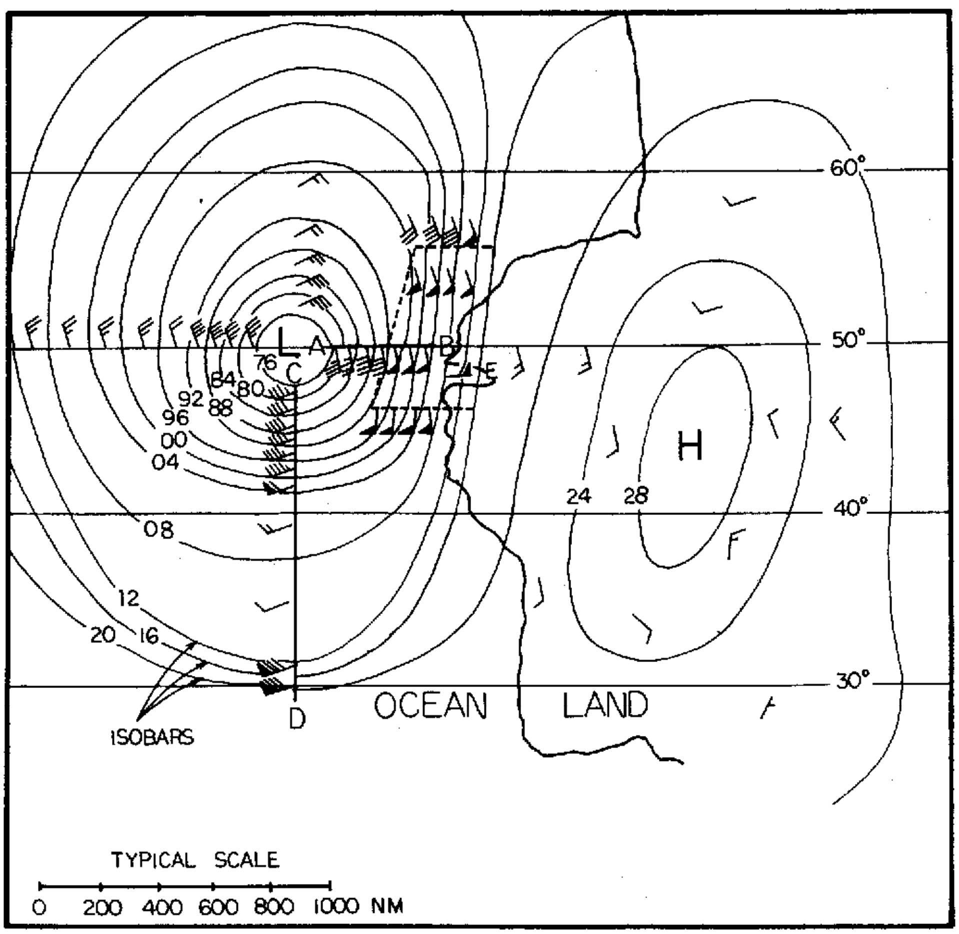


FIG. 1 WINDS AROUND LOW (L) AND HIGH (H) PRESSURE CENTERS IN THE NORTHERN HEMISPHERE.

The winds shown in Figure 1 would be typical for a weather pattern having the isobars oriented as they are, but each pattern is different and has to be judged on its own merits. In some cases, the isobars will be much closer toward the center of the low, and the storm will have much higher winds toward the center despite the curvature of the isobars. Wind speed is also affected by the stability of the air mass.

If the air is colder than the water, it is heated from below, which causes the air to rise and mix with the air aloft. The effect of this is to cause higher winds aloft to be brought to the surface in strong gusts and a general increase in the prevailing wind. This is why cold winds from the land during late fall through early spring can be very hazardous to vessels in more northerly latitudes. The cold wind gets a strong bite on the water, causing steep waves and perhaps icing due to the sub-freezing temperatures and flying spray. Conversely, if the air is warmer than the water, it is cooled from below and does not readily mix vertically. The winds creating the waves are not as likely to be as strong as they otherwise would be in this case. This is not to say, however, that high seas cannot be created by warm winds, for they certainly can be.

By using the most recent surface weather maps and surface weather prognosis (forecast) maps, we can tell whether the wind will be coming from colder land or sea ice areas. Unfortunately, most of the surface weather maps we get have few actual wind speeds and directions plotted on them. (However, the Navy's Preliminary Surface Analysis charts from station NPM at Pearl Harbor do have a number of computer derived surface winds.) We are faced, in most cases, with the task of making an estimate ourselves.

Determining the wind speed and direction at a given point on the surface weather map can be done using certain techniques that are too involved to be shown here, but we should be aware of the important factors involved. Basically, the speed depends on the distance between the isobars bracketing either side of the point of interest; the latitude of the point; the radius of curvature of the isobars bracketing the point; and the type of curvature of the isobars (i.e., are the isobars curving around a low or a high pressure center?). Additionally, the stability of the air as discussed above must be considered.

As a very general rule, isobars that are drawn at four millibar intervals spaced 1° latitude (60nm) apart will create winds of gale force or higher in the areas where the isobars appear very curved and storm force winds in areas where the isobars appear straight or nearly so. Gale force winds are 34-47 knots and storm force winds are 48 knots and up. Winds can be much higher than this for 1° isobaric spacing in fjords, passes, and between islands where the air is funneled by the land.

Similarly, if the distance between isobars is ½° latitude, the wind speeds double in both cases, and if the spacing is 2° of latitude, the wind speed is half what it is at 1° spacing. We have assumed that the curvature and stability of the air mass is the same in all these cases.

If the map you are using has eight millibar isobaric intervals, then the assumptions we have just discussed do not apply very well because we do not know where the intervening isobars should be drawn. When applying these rules, always check to determine if the isobars are drawn at four millibar intervals and that they are drawn in smooth, not wiggly lines which come together and spread apart erratically. Isobars drawn in this fashion have not been drawn to acceptable standards.

WAVES

Waves may be nothing more than tiny ripples on a glassy sea to gigantic cascading walls of water capable of terrible damage. For example, over the period October 22 and 23, 1968, a storm off the British Columbia coast sent a 100 foot wave into the drilling rig SEDCO 135F in Queen Charlotte Sound. Fortunately, the structure had been designed so that the working platform was more than 100 feet above the water level. Anyone who has spent any length of time at sea will sooner or later have his own stories of harrowing experiences with waves.

Through the use of radiofacsimile wave height prognosis charts and surface weather maps, some hazardous circumstances can be anticipated, though not all, as these extremely unusual circumstances are not that frequent and are beyond present day forecasting methods. The eight factors most important in creating waves are:

1. Wind speed.
2. Wind duration.
3. Length of wind fetch (distance of water over which the wind blows).
4. Width of the body of water (not a factor in open ocean).
5. Depth of water.
6. Set (direction) and drift (speed) of water currents.
7. Air and water temperature differences.
8. Rate of rainfall.

Waves on the open ocean will continually develop under a given wind speed, duration, and fetch until they reach the maximum height they can attain for those conditions. Table II illustrates this point. Notice that most of the development occurs with a fetch of only

100 nm and that longer fetches do not dramatically increase the heights except at higher wind speeds.

The faster the wind, the higher the waves get in a shorter period of time. This can also be verified from Table II. In their initial stage of development, waves are steeper because the wind energy is "pumped" in faster than the waves can adjust. The shallower the water, the smaller the locally generated waves will be; however, depths of less than about 100 fathoms are needed to observe this effect. Higher waves coming from off the open ocean over shallower banks are going to become higher and steeper as they enter the shoaler water.

A current of over two knots flowing in opposition to the wind and/or waves or within about 45° of them will create higher and steeper waves than if the current flowed with them. Strong tidal currents, such as in Cook Inlet, Alaska or strong ocean currents, such as the Japanese Current or Gulf Stream, can have profound effects on the height and steepness of the waves.

Cold air blowing over warmer water will create higher and steeper waves than a warm wind having the same speed blowing over colder water. The waves will also develop in a much shorter period of time with the cold wind. This factor is important in the fall, winter, and spring months in northerly latitudes when air comes off the colder land masses. By using the surface weather charts and surface weather prognosis charts, a reasonable estimate of wind direction can be made.

Finally, heavy rainfall helps reduce the development of waves because the less dense fresh water tends to slide across the sea surface when the wind blows, which retards the transfer of energy from the wind to the sea. This effect is most noticeable in tropical climates where extremely heavy downpours can almost quench the waves.

Marine forecasts and wave prognosis charts give predictions of the *significant* wave height—the height of the waves that turns out to be very close to what the experienced mariner would report them to be. As mentioned earlier, it is the average height of the highest one third of the waves. The following relationships are useful when using forecasts or wave charts:

- Most frequent wave height = 0.5 x significant wave height.
- Average wave height = 0.6 x significant wave height.
- Highest 10% of the waves = 1.3 x significant wave height.
- One wave in 1,175 is likely to be 1.9 times the significant wave height.
- One wave in 300,000 may be up to 2.5 times the significant wave height.

TABLE II

Significant Wave Height (ft.)
Versus Wind Speed, Duration, Fetch

20 KNOTS

Wind Duration (hours)	Fetch (nm) 20	50	100	200	300	400	500
1	0.8	0.8	0.8	0.8	0.8	0.8	0.8
2	1.5	1.5	1.5	1.5	1.5	1.5	1.5
3	2.4	2.8	2.8	2.8	2.8	2.8	2.8
6	2.4	3.9	4.0	4.0	4.0	4.0	4.0
12	2.4	3.9	4.3	4.6	4.6	4.6	4.6
24	2.4	3.9	4.3	4.9	5.0	5.0	5.0

30 KNOTS

Wind Duration (hours)	Fetch (nm) 20	50	100	200	300	400	500
1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
2	4.9	4.9	4.9	4.9	4.9	4.9	4.9
3	5.6	7.0	7.0	7.0	7.0	7.0	7.0
6	5.6	8.4	9.8	9.8	9.8	9.8	9.8
12	5.6	8.4	11.0	11.0	11.0	11.0	11.0
24	5.6	8.4	11.0	11.0	11.0	11.0	11.0

40 KNOTS

Wind Duration (hours)	Fetch (nm) 20	50	100	200	300	400	500
1	4.2	4.2	4.2	4.2	4.2	4.2	4.2
2	9.1	11.0	11.0	11.0	11.0	11.0	11.0
3	9.1	15.0	15.0	15.0	15.0	15.0	15.0
6	9.1	16.0	18.0	18.0	18.0	18.0	18.0
12	9.1	16.0	18.0	20.0	20.0	20.0	20.0
24	9.1	16.0	18.0	20.0	21.0	21.0	21.0

50 KNOTS

Wind Duration (hours)	Fetch (nm) 20	50	100	200	300	400	500
1	8.4	8.4	8.4	8.4	8.4	8.4	8.4
2	15.0	20.0	20.0	20.0	20.0	20.0	20.0
3	15.0	25.0	25.0	25.0	25.0	25.0	25.0
6	15.0	25.0	29.0	30.0	30.0	30.0	30.0
12	15.0	25.0	29.0	32.0	32.0	32.0	32.0
24	15.0	25.0	29.0	32.0	32.0	32.0	33.0

60 KNOTS

Wind Duration (hours)	Fetch (nm) 20	50	100	200	300	400	500
1	16.0	16.0	16.0	16.0	16.0	16.0	16.0
2	21.0	32.0	32.0	32.0	32.0	32.0	32.0
3	21.0	35.0	39.0	39.0	39.0	39.0	39.0
6	21.0	35.0	42.0	44.0	44.0	44.0	44.0
12	21.0	35.0	42.0	46.0	46.0	46.0	46.0
24	21.0	35.0	42.0	46.0	46.0	47.0	47.0

70 KNOTS

Wind Duration (hours)	Fetch (nm) 20	50	100	200	300	400	500
1	28.0	28.0	28.0	28.0	28.0	28.0	28.0
2	28.0	47.0	47.0	47.0	47.0	47.0	47.0
3	28.0	47.0	53.0	53.0	53.0	53.0	53.0
6	28.0	47.0	53.0	56.0	56.0	56.0	56.0
12	28.0	47.0	53.0	56.0	56.0	56.0	56.0
24	28.0	47.0	53.0	56.0	56.0	56.0	56.0

NOTE: This table is only valid in open ocean area over 600 ft. deep and where water currents are less than two knots. Significant wave heights are in feet. (Significant height is the average of the highest one third of the waves.) Maximum wave heights may be up to twice the height shown in the table.

When using a forecast or wave chart, keep in mind that the highest waves are not predicted and that waves ninety percent higher than the predicted height occur occasionally if the forecast proves correct. Fortunately, waves 2.5 times as high as the significant height are rare, and a career at sea can be spent without experiencing one.

FOG

Fog occurs when the air next to the sea surface is cooled enough so that the water vapor present in the air condenses into droplets. Fog may also occur when rain falls through an underlying layer of much cooler air in which the winds are too light to mix the air vertically. The additional water vapor from the rain brings the air layer to saturation and fog forms. The densest and most persistent fogs are due to the movement of warm moist air from southerly latitudes to northern latitudes or to areas where cold ocean waters exist.

One of the foggiest areas in the world is in the vicinity of the Aleutian Islands during the late spring to early fall months due to warm air from southerly latitudes moving north along the west side of a high pressure weather pattern that normally dominates the eastern Pacific Ocean at this time. As the air moves northward, it encounters colder water temperatures, eventually cooling enough to form fog. The resulting fogs can persist in winds of over 30 knots for days at a time. The coasts of California and Oregon are other likely places for very extensive fog banks during the summer months because of the cold water just off the shoreline. Sometimes the fog extends along the coasts of Washington and British Columbia.

Therefore, by keeping track of the weather pattern on the surface weather map, it can be seen where warmer air from the south might be carried northward into the Alaskan region. There will almost definitely be fog along the U.S. West Coast if a high pressure system dominates the region. Clear nights and calm or light winds are conducive to its formation in bays. Some of the surface weather maps have areas outlined on them where fog is located at the time of observation for that chart. A change in the weather pattern, such as the approach of a front or strong winds can be watched for to clear out the fog. Also, a change in the wind direction in which air comes off the land will help clear the fog. In places where sea breezes occur during the summer, such as San Francisco or Cook Inlet, Alaska, fog may be carried toward shore into adjacent bays and persist for days even in 20 knots of wind.

One other type of fog occurs and will only be mentioned briefly here. Sea smoke or steam fog occurs when very cold and dry air flows out from frozen land masses over warmer water. These wispy streamers of fog may form ice on vessels, but it is usually not hazardous.

SUPERSTRUCTURE ICING

When the air temperature drops below about 27°F, spray from wind-blown wave tops and from spray thrown up by the vessel itself will freeze on exposed areas of the vessel. The rate of accumulation can become phenomenal with tragic consequences for the vessel and her crew. Cold winds off land or ice areas are the most likely to cause icing, especially in areas off the coast of Alaska. The surface weather and surface weather prognosis charts can be used to forewarn of offshore winds exceeding 15 to 20 knots. The winter months, of course, are the favored months for icing to occur.

The subject of icing is a fairly involved one since the type of vessel and her stability characteristics enter into the factors that have to be considered. Vessels with high freeboard, such as ocean liners and large cargo ships, will not be affected by icing as much as smaller vessels because the spray may not be flying up high enough to reach topside structures. This also depends on how big the waves are and which way the vessel is heading. A fishing trawler with much lower freeboard is very susceptible to icing as records of sinkings each year in Alaska will attest to. The further offshore, the more chance the air has to be warmed by the sea, so areas closer to shore (say within 150 to 200 nm) can be areas where icing is most likely to occur. The state of the sea also needs to be taken into account when considering the severity of icing because waves will be bigger further offshore in a wind blowing from the land.

The western half of a deep low that has gale to storm force winds or the eastern edge of a strong high pressure system are the types of weather patterns that can cause icing conditions. Figure 2 shows an icing situation.

The air temperatures will be well below freezing in the area approximated by the dashed line as the wind comes off the frozen land mass during winter. As the air continues to flow further to sea, it is heated by the water until it reaches a temperature near that of the water itself. In the northeastern Pacific Ocean, temperatures less than 32°F occur less than about five percent of the time below 50°N over the open ocean. However, the closer to land, the greater chance of encountering subfreezing temperatures occurs if the wind comes from the land, even at latitudes below 50°.

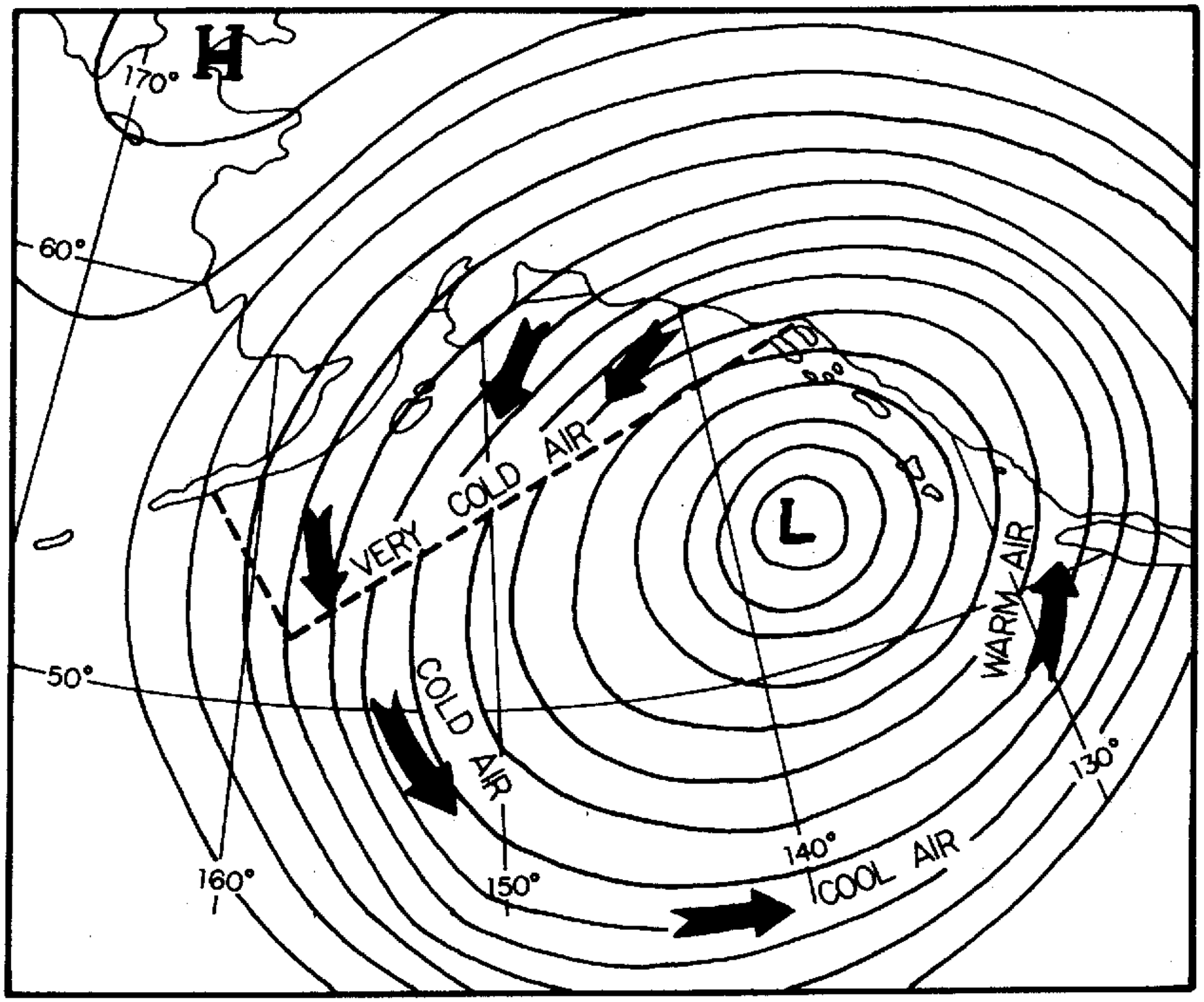


FIG. 2. SUPERSTRUCTURE ICING SITUATION FROM A LOW PRESSURE SYSTEM SHOWN ON A SURFACE WEATHER MAP.

Icing due to sea smoke is usually not as hazardous as that from freezing spray because the wind is usually light, and the only icing is due to the freezing of the fog droplets on the vessel. Because of the calmer seas, it is often possible to send people topside to knock some of the accumulation off.

SECTION III

HOW TO USE WEATHER MAPS

There are two types of weather maps:
analysis and prognosis maps.

ANALYSIS MAPS

These maps, as the name implies, are based on weather observations from which patterns of highs and lows as well as the locations of weather fronts are drawn. Much of the accuracy of the chart depends on the skill of the meteorologist or analyst who draws the pattern based on his interpretation of the observations.

Undoubtedly, the surface weather analysis charts are going to be the most frequently used because they are the ones which depict what the actual pattern looked like at a certain time. Weather observations are taken world wide at specific times (0000, 0600, 1200, and 1800 GMT). From these observations and the use of satellite pictures of the cloud tops, the surface analysis charts are drawn for the ocean and land areas every six hours. However, of the U.S. radiofacsimile sources, only the Navy broadcasts a chart for each of these times. The NWS charts are transmitted for the observations taken at 0000, 1200, and 1800 GMT.

There are two important factors to keep in mind when using any surface analysis map. First, the weather pattern over the ocean outside the major shipping lanes may be based on very few observations. In some cases, only one observation may be available for an area larger than Texas. Meteorologists have techniques for partially compensating for the lack of observations, but the locations of low and high centers may be in error by more than a hundred miles. Aboard ship we have no indication how many observations were used for each chart, so whether the analysis is precise or not has to be left to trust. Second, the analysis chart is not showing the pattern as it exists at time of receipt aboard the ship, but is the pattern as it was some three to six hours earlier depending on which maps we elect to copy. This will be important in those weather situations that are changing rapidly, such as deepening lows moving at 40 knots. By the time we receive the chart, the lows may be from 120 to 240 miles from where they are shown on the analysis. This can be compensated for by simple methods that will be discussed later.

Use of a shipboard barometer along with changes in the wind and other weather elements are valuable aids to use in checking for changes in the weather pattern. We can relate the weather map to what we actually see is happening. The shipboard barometer reading with which comparison to the map is made must give a true sea level pressure reading, which usually means that the barometer reading has corrections applied to compensate for elevation and instrument error. All isobars on the chart are for sea level pressure, and the reading we use for comparison with the chart must be the one taken at the time of observation used on the analysis. Do not be surprised if your reading differs somewhat from the pressure at your position on the analysis. Your weather report (if you are involved with the weather observation program) may not have been used on the analysis for one reason or another (Sometimes reports get lost in transmission to the various meteorological centers!). If you are not in the weather observing program, then your observation could not have been used in any case. The observations were analyzed using the best information available, and some guesswork has to be used in placing isobars where data do not exist. Besides the surface weather analysis charts, there are some others that have more specialized applications.

The sea surface temperature (SST) analysis charts consist of isotherms (lines connecting points of equal temperature) delineating regions of various water temperatures. Since changes in ocean temperatures take place rather slowly as compared to the atmosphere, these maps may be updated only once or twice a week. They are derived from measurements of sea temperature from engine intake temperatures, bathythermograph measurements, and weather satellite pictures.

PROGNOSIS CHARTS

The prognosis ("prog" for short) charts normally used are the surface weather prog, the significant wave height prog, and perhaps the 500 millibar prog. There are other prognosis charts, such as weather depiction charts showing the types of clouds and weather expected over the ocean, but most information needed is available from the three types of charts mentioned above.

The prog charts showing weather patterns at the surface and the 500 millibar level (about 4,800 to 6,200 meters above the earth's surface) are produced by computers. As might be expected, the further into the future the prognosis, the more inaccurate it is likely to be. Thus, prog charts that predict for 12 to 48 hours ahead will usually be more precise than ones that are for 72 hours, especially in fast changing weather situations.

In order to predict the weather pattern beyond 36 hours, computer prog charts are needed because the method of simply advancing highs, lows, and fronts based on their previous movements on the weather analysis maps become very unreliable. Experience has shown that the 500 millibar progs are usually more accurate in predicting the upper level weather patterns than the surface weather progs are in predicting sea level patterns. The upper level progs can be used to locate the jet stream as well as locations of upper highs and lows; and from this information, a judgement can be made of whether or not the weather will generally be stormy, remain about the same, or improve.

The jet stream is a ribbon of fast moving air often found between about 15,000 feet to over 40,000 feet with speeds varying from 50 to over 200 knots. It can be located on the 500 millibar prog by simply reading the wind speeds plotted on the chart which are about 50 knots or higher. Lows at the surface of the earth often travel beneath the jet, following it like a leaf in a creek. Surface lows, when located underneath a jet stream, often move at speeds from about one-third to one-half that of the jet found at 500 millibars. Jet streams sometimes split into two parts with one part heading in a northerly direction and the other branch in a southerly direction. Weather fronts moving into such a "split" are literally torn in two with parts of the cloud mass branching off into the two streams. The area underneath or east of the split may experience very nice weather as a result.

The lines drawn on the 500 millibar prog look similar to isobars, but instead of being lines connecting points of equal pressure, they connect points of equal elevation where the pressure measures 500 millibars. They are called contour height lines or simply contours. The closer the contours are together, the faster the winds. The Navy broadcasts a whole series of 500 millibar progs as well as other upper level progs.

RECOGNIZING WEATHER PATTERNS

The variety of weather patterns is virtually without limit, and any general rules made about the various patterns have strings of exceptions. This makes weather prediction a fascinating and sometimes frustrating job.

Typical progressive weather pattern: Lows and highs generally move from a westerly direction toward an easterly direction. Fig 3 shows this.

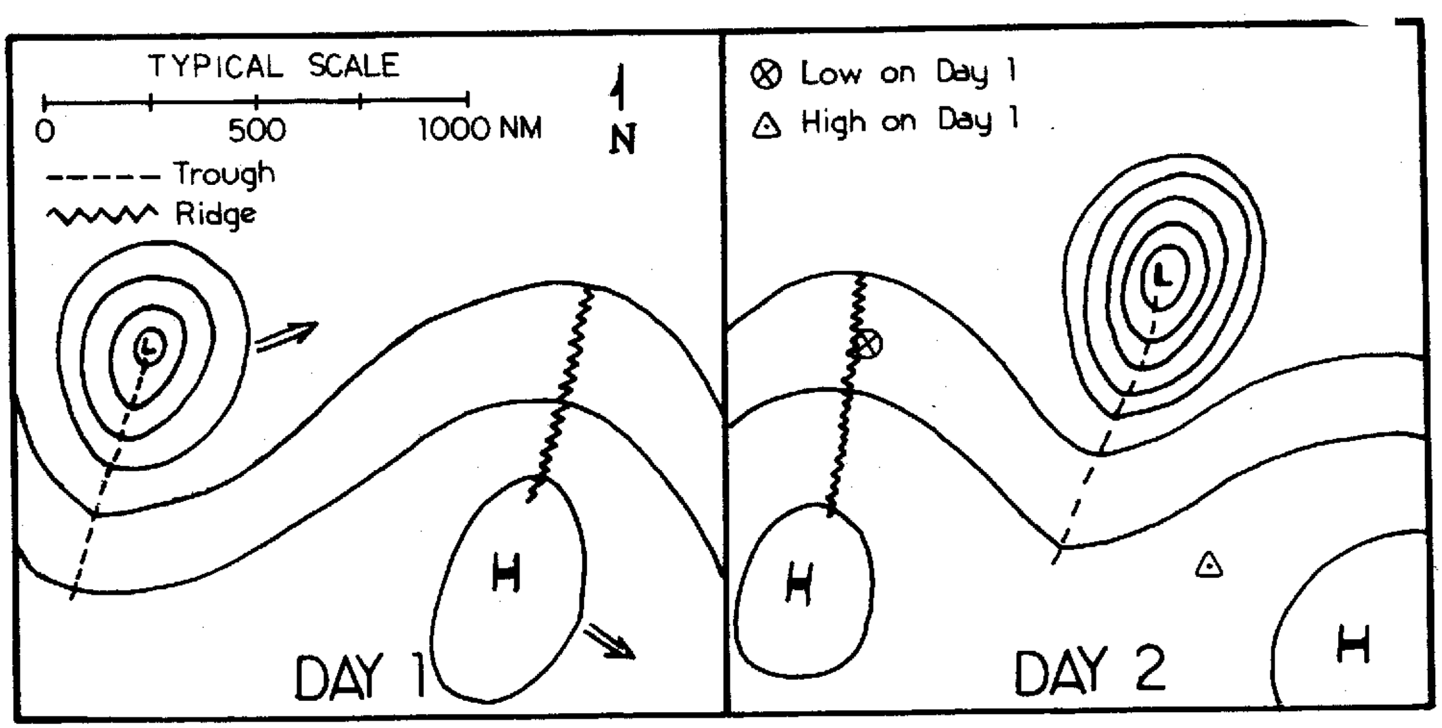


FIG. 3. TYPICAL PROGRESSIVE WEATHER PATTERN ON A SURFACE WEATHER MAP.

In a very general sense, weather patterns shift eastward with time, but there are exceptions to this, which is why radiofacsimile maps are so useful. Sometimes a pressure center may move north or south, and, in some cases, even west. Figure 3 shows a trough with the low center and a ridge with the high center. A trough is often a region of cloudiness and inclement weather as well as the area where weather fronts form and move away from the low pressure center. A ridge is often, but not always, a region of fair weather. Areas west of the ridge axis may be quite cloudy and windy, and areas slightly east of a well-developed ridge may have very pleasant weather. As you get further west or east of the ridge axis, you get closer to adjacent troughs and more adverse weather. It should be pointed out that the troughs and ridges may be oriented in any direction, not just as they are shown in the figure.

Similarly, at the 500 millibar level, ridges and troughs exist, and much can be deduced about the movement of surface lows. If the contours are oriented west-east, the low pressure centers move west-east. When the contours bend around a ridge, then the lows will move from a southerly to a northerly direction on the west side of the ridge and from a northerly to a southerly direction along the east side of the ridge. These movements occur if the 500 millibar ridge is well developed and nearly stationary or stationary. If the high is not well developed or the entire pattern is shifting eastward with time, the lows will move accordingly. Use the 500 millibar progs to determine the movement of the pattern and note the positions of ridge and trough axes using previous progs to see how rapidly they have moved compared to the latest prog chart. Figure 4 shows some typical jet stream paths over the eastern North Pacific Ocean.

Track I: Lows follow a northwest to southeast track along the coasts of Southeast Alaska and British Columbia often bringing snow to the Pacific Northwest during winter; but during the rest of the year, rains are usually not too heavy with lows following this trajectory.

Track II: Lows following this path bring storms to areas between 20°N and 40°N and may be particularly devastating to Southern California. Areas north of about 40° may have very nice weather. It is unusual for the jet stream to remain at this low latitude off the southern California coast, and as it drifts back northward, lows move into Oregon, Washington, and finally, Southeast Alaska.

Track III: Lows move west to east on this track into the Pacific Northwest and British Columbia.

Track IV: Torrential rains and unseasonably warm temperatures during the winter and spring months occur in the Pacific Northwest with this track because the lows bring warm and moist subtropical air. Seas will be stormy from the coast to several hundred miles offshore.

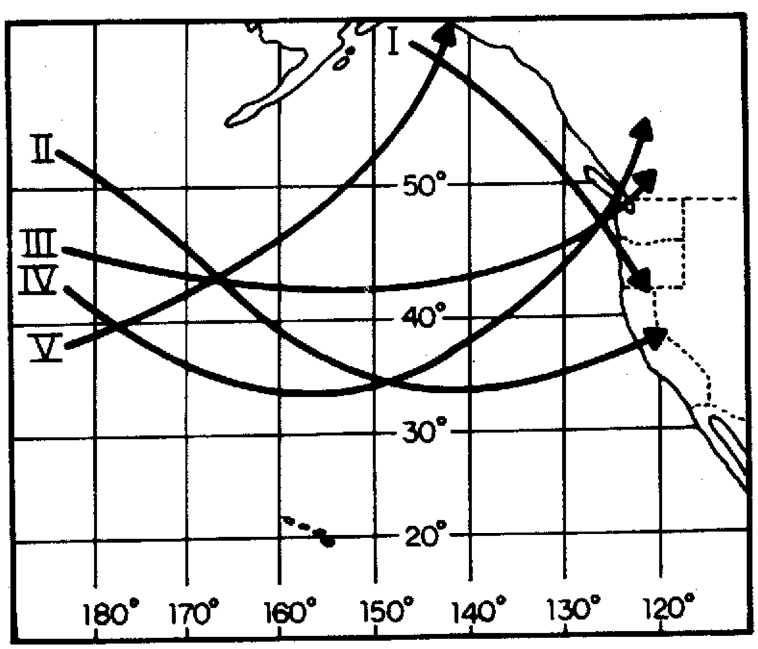


FIG. 4 TYPICAL JET STREAM PATHS OVER THE EASTERN NORTH PACIFIC OCEAN.

Track V: Unseasonably mild and wet weather is brought to eastern Alaska, and the Gulf of Alaska remains subject to a series of storms.

Explosive development of storms: Certain weather patterns can create very fast-moving and intensifying storms over a period of less than two days. One of the most notable storms of this type occurred along the Oregon, Washington, and British Columbia coasts over the period October 12 and 13, 1962. Called the Columbus Day Storm, it originated five or six days earlier when an old typhoon in the far western Pacific moved northward and got caught under a strong jet stream that had winds of over 100 knots at the 500 millibar level. The typhoon changed into a low pressure system that deepened extremely fast when it encountered a 500 millibar pattern similar to that shown in Figure 5.

The situation shown in this diagram presents an unusual risk to mariners because of the rapidity with which the storm develops. The movement and changes in the surface low are shown in panel A. A rather weak low, one which might be ignored because it is more than a thousand miles away on Day 0, comes under a strong jet stream shown in panel B. The central pressure of the surface low is shown for each of the days in panel A. However, by following the low on the surface map, it can be noted that it is moving rapidly eastward and deepening by Day 2. If we happen to be, say 1000 miles north of its position on Day 2, and have only been using surface weather analyses to follow its progress, we are likely to be unpleasantly surprised less than 36 hours later. Using the surface prognosis charts and the 500 millibar progs could have given us an additional 24 to 36 hours of warning, and we could have taken avoiding action. The low enters the area where the jet stream makes a rapid bend to the north on Day 2 and is now beginning to rapidly deepen and head straight for us.

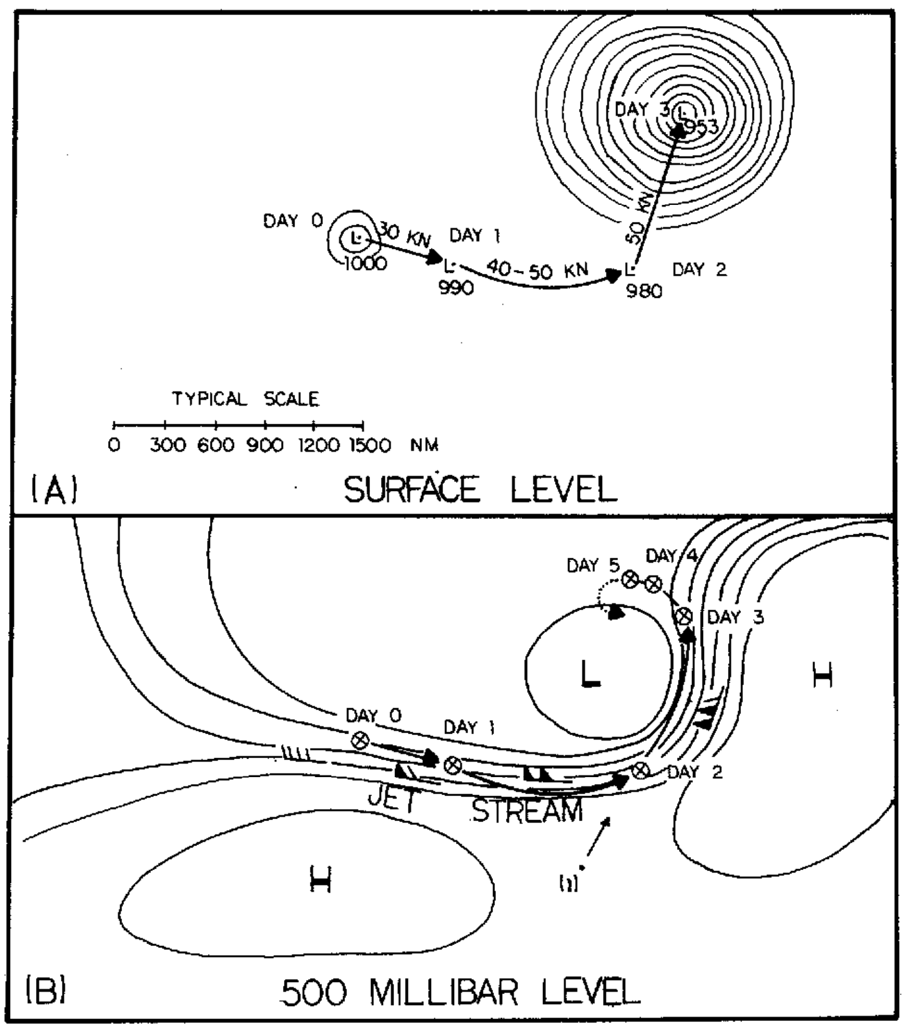


FIG. 5. EXPLOSIVE DEVELOPMENT OF A STORM.

Panel B shows a strong jet stream of 100 knots and higher that runs west to east and then curves northward along the west side of a well-developed high. The 500 millibar progs are usually fairly accurate picking up this type of development, often to 72 hours ahead. The surface low rapidly deepens in the area shown by the heavy lines, going from 980 millibars to 953 millibars by Day 3. (Lows as deep as 928 millibars have been recorded in the Gulf of Alaska!) As the low nears the heavy line shown at Day 3, it slows down and starts to slowly weaken, and it may drift northwest and recurve back toward the southeast. Often times, another low follows the first one by a day or two and may become a ferocious storm, too, with winds over 70 knots. It has been observed that the first low may move southeastward while the second low moves northward and then northwest so that the first low eventually passes to the south of the second low. This is called the "dumbbell effect" (see Figure 7).

The low on the surface map does not necessarily have to come from the west for this explosive development to happen. Cases have been observed where a low drifted northward from position 1 shown on panel B. Surface lows that have their origins in the subtropics or tropical regions should be followed very closely, especially if the 500 millibar progs show a pattern similar to that in panel B.

Conversely, some lows get separated from the jet stream. They will move erratically or very little at all until either the jet stream comes over them again or they simply dissipate a few days to over a week later.

The Omega Block: This pattern at the 500 millibar level is named after the Greek letter Ω because the contours assume a shape similar to the letter. The high pressure pattern at the surface level is strong and very large, often covering the entire northeastern Pacific Ocean. The Omega Block is a special case of a blocking high shown in Figure 6.

A blocking high may be welcomed or cursed depending where you are in relation to it. A blocking high prevents the normal west to east movement of lows and weather fronts and is one of the most persistent patterns of all when it assumes the shape of an Omega as shown in panel A. Blocking highs over the U.S. West Coast, for example, have been known to bring warmer temperatures to Anchorage, Alaska than those occurring at Miami, Florida! The areas west and east of the high remain stormy, often for weeks on end.

Use the 500 millibar progs to see where highs of considerable development occur (panel A) and also on the surface weather analysis charts (panel B). The high need not be oriented north-south as shown in the figure, but may be canted one direction or the other. In some cases, the lows on either side of the blocking high, especially if it is an Omega Block, may remain nearly stationary, so use the surface progs to see how they are expected to move. The region under the surface high away from the tight isobar regions along the edges will usually have fine weather, light winds, and possibly, fog. A blocking high may last for as short as three to five days or longer than a month and can develop anywhere over the ocean. Often times the pattern shifts

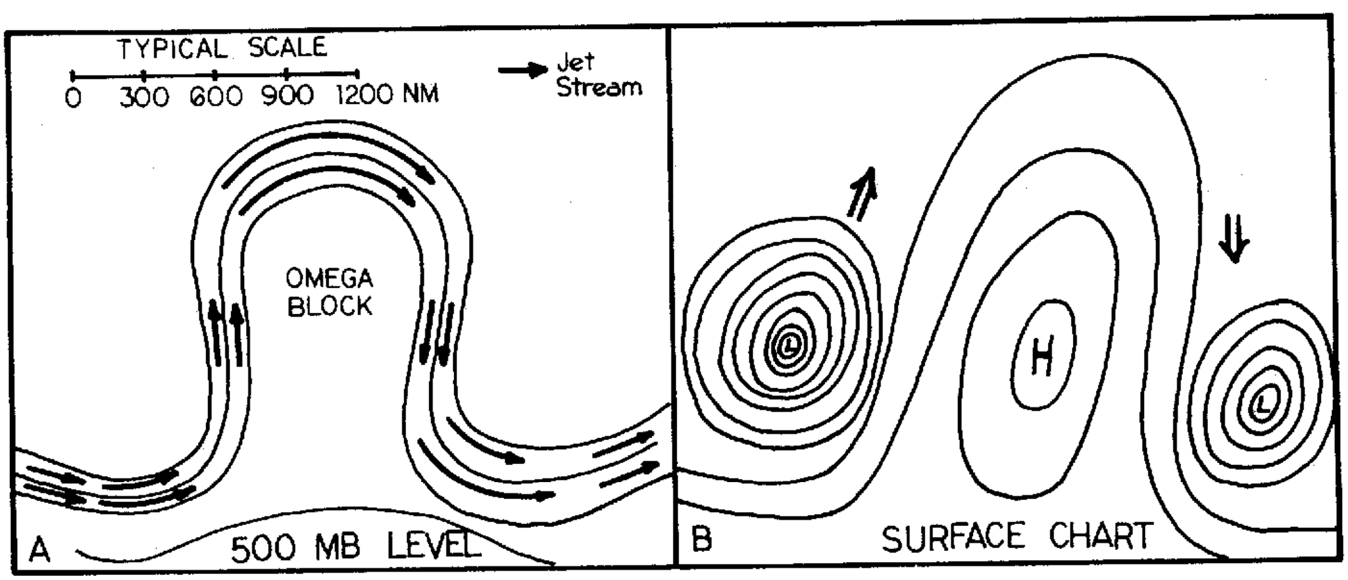


FIG. 6. BLOCKING HIGH AT THE 500 MILLIBAR AND SURFACE LEVEL.

westward. It is common to have a jet stream that passes well to the south of the high, which will carry lows eastward underneath the high. Omega Blocks and blocking highs make ideal weather for crossing the Gulf of Alaska.

Fronts and frontal movement: The typical sequence of events in the life cycle of weather fronts is shown in Figure 7. The deeper the low, the stronger the fronts are, and confused seas with wind waves from one direction and swell from another may occur with the passage of a front.

Panel A: Wave develops on frontal zone separating cold air from warm air.

Panel B: Low center develops and deepens. Winds increase around the low. Low tends to move in the same direction as the orientation of the isobars in the warm sector.

Panel C: Cold front begins to overtake the warm front, forming an occluded front. Low continues to deepen and winds increase.

Panel D: Low (primary low) reaches its maximum strength when the warm front has become totally occluded by the cold front. Sometimes another low (secondary low) develops to the south of the primary depression and becomes a very potent storm that may become stronger than the primary low.

Panel E: Occluded front moves away from the primary low, and the depression begins to weaken.

Panel F: Secondary low deepens. The region between the two lows has light winds because the isobars are far apart. However, gales still occur in the region enclosed by the isobars surrounding each of the low centers. Note how the two lows rotate around each other like a rotating dumbbell.

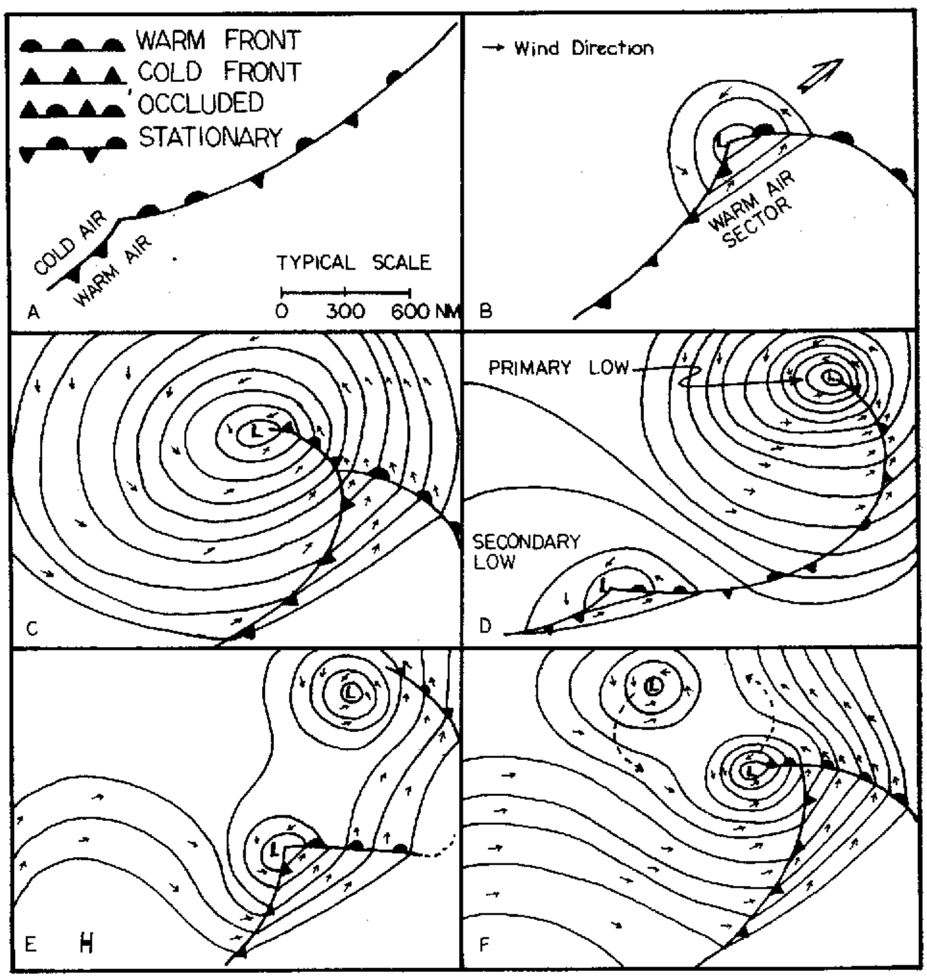


FIG. 7. DEVELOPMENT OF FRONTS AND THE "DUMBBELL EFFECT." ALL THE PANELS SHOW THE WEATHER PATTERN AT SEA LEVEL. ARROWS INDICATE WIND DIRECTIONS.

As mentioned in the Glossary, a weather front is the narrow zone separating two air masses of different densities from each other. The weather associated with them may range from nothing more than an increase in cloudiness to extremely strong winds and torrential downpours. Fronts that become stationary, say along the western edge of a blocking high, may bring day after day of steady precipitation to those areas within a couple hundred miles on either side of the front. When using surface weather charts to locate fronts over the open ocean, keep in mind that the number of observations used to locate them may be quite small, so the positions are only approximate. Weather satellites have improved the locating of fronts, but there are still difficulties in exactly finding where the fronts touch the sea surface. Table III lists some of the weather features associated with fronts.

Tropical weather: In the tropics, during the late fall through spring months, extremely heavy rainfalls may occur when lows and fronts move into the area. Normally, lows as experienced in the more northern latitudes do not move into areas south of about 20° to 25° and neither do fronts. When a front moves into the Hawaiian Islands, for example, the northeast trade winds are replaced by gale force southerly winds until the front passes through, and warm, humid air from the equatorial regions is brought into the area. This causes heavy rains on the normally leeward sides of the islands. Similarly, depending on the location of a low center, southerly winds may occur with the low as well as a generally unstable atmosphere in which heavy rainfalls occur at all locations. Then, of course, there are also specifically tropical weather systems (see tropical depression, tropical storm, hurricane, and typhoon in the glossary).

The subject of tropical weather is an interesting one beyond the scope of this publication, but some of the references listed in the bibliography cover the subject quite well. One of the most important facts to consider is that it might prove risky to cross in front of the projected path of a hurricane or typhoon unless it is certain that the vessel will not encounter the swell generated by the storm. An engine casualty or other emergency could prove embarrassing.

BASIC FORECASTING TECHNIQUES

The technique used with surface analysis charts in tracking the weather is based on the idea that the past is an indicator of the future. A minimum of two surface weather analysis charts received each day is recom-

TABLE III.

FRONTAL WEATHER

	Warm Front Approaching	Warm Front Passing	Warm Air Sector	Cold Front Approaching	After Cold Front Passes
BAROMETER READING	falling	stops falling; may slightly rise	little change, then falling	falling to rapidly falling	rising
WIND(over open ocean)	SE to S, increasing	S to WSW with possible great increase	steady and strong; possibly becoming SE to S as cold front nears	strong SE to S	rapid change to SW to NW; may increase
TEMPERATURE	rising slowly	rising	little change	little change	sudden drop
PRECIPITATION	becoming steady; drizzle to heavy rain or snow	rain or drizzle	rain, drizzle, fog	heavy rain; possible thunderstorms	heavy rain, hail, or snow showers; then intermittent showers
VISIBILITY	deteriorating	poor	poor	improving rapidly	good, except in showers

NOTE: The effects listed in the table are the ones ordinarily observed. Sometimes another cold front follows several hundred miles behind the first cold front, particularly in higher latitudes during winter and spring months. An occluded front may act like a cold front or a modified warm front, depending on the strength of the front and the temperature of the air behind the front.

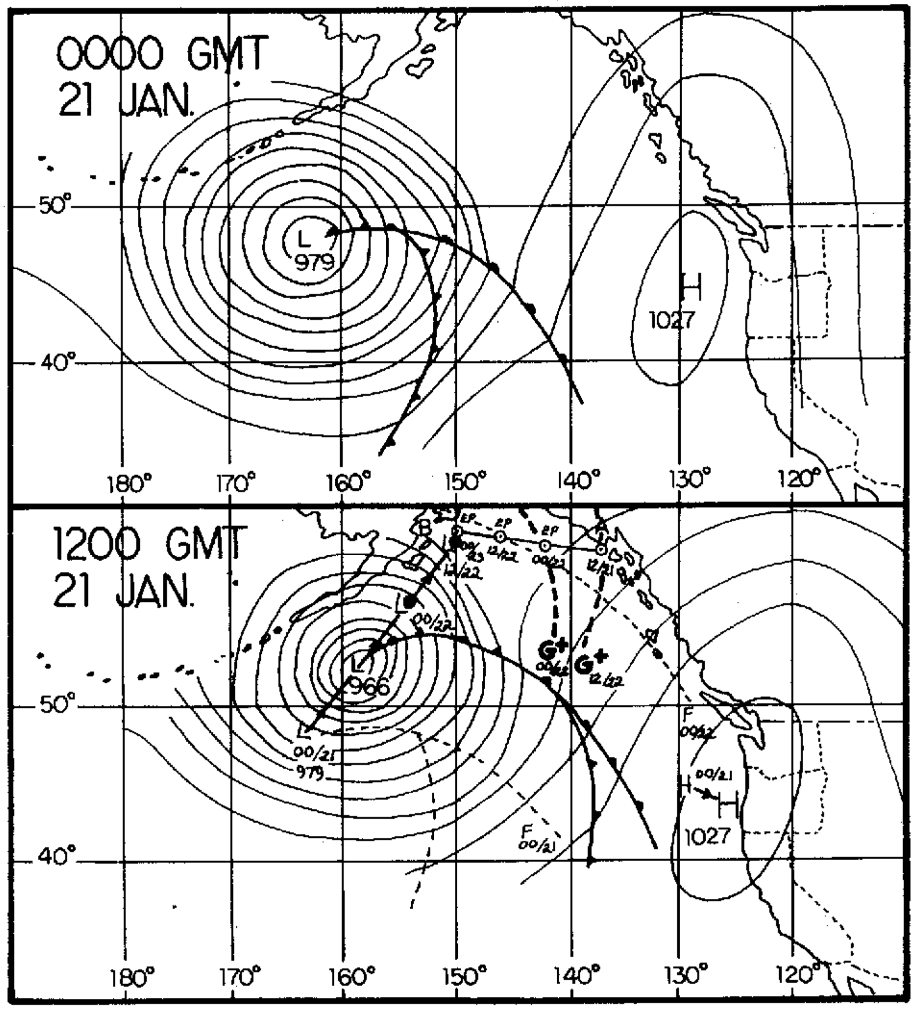


FIG. 8. FORECASTING POSITIONS OF LOW AND HIGH CENTERS, FRONTS, AND STRONG WIND AREAS USING TWO SURFACE WEATHER MAPS.

mended and more than this when the situation is rapidly changing or critical operations requiring the most up-to-date information are involved.

Take the latest map and the one previous to it (no more than 18 hours previous, however) and then plot the earlier locations of the high and low centers and fronts that are of interest to you. Plot these on the latest chart. Based on the past movement between the two maps, project ahead by noting the positions of these features at 12 and 24 hours into the future on the latest map. Another useful feature to advance is the region of closely spaced isobars in which gale force or stronger winds are likely. (These isobars will usually be about 1° of latitude or less apart.) Figure 8 shows how this is done.

In the figure, two maps 12 hours apart, 0000 GMT/21 January and 1200 GMT/21 January, are used. Let's assume our planned trackline is from A to B (Cape Spencer to Kennedy Entrance, Alaska) and the speed of our vessel is 12 knots.

On the 1200 GMT/21 chart plot the 0000 GMT/21 (00/21 for short) position of the low center and its central pressure (e.g., L 979/00/21). Then advance the distance it has traveled between the two charts and label positions of the low 12 and 24 hours later (e.g., L 00/22 and L 12/22). Similarly, the 00/21 position of the front is noted on the latest map and is advanced 12 and 24 hours ahead. Label the arcs representing the front (light dashed line) F 00/22 and F 12/22. However, the front should be onshore by 12/22, so the position 24 hours ahead need not be shown. Finally, we notice that the isobars are closely spaced around the low and are advancing toward our trackline. Using a pair of dividers or a drawing compass, measure the distance from the center of the low at 12/21 to the outermost closely spaced isobar and transfer this distance using the predicted locations of the low center 12 and 24 hours ahead as the points from which to swing the arcs. The region between these arcs and the respective predicted positions of the low center is the strong wind area. Label these arcs G + 00/22 and G + 12/22 (heavy dashed lines). Areas between the G + arcs and the predicted positions of the low center can be expected to be stormy because the low has deepened from 979 mb to 966 mb between the two weather analysis maps and is unlikely to weaken because the front has not become entirely occluded by 12/21.

The estimated positions of our vessel along the trackline for 12, 24, and 36 hours ahead are shown as circles around a dot and labeled EP 00/22, EP 12/22, and EP 00/23. Our actual position at 12/21 is also shown (point A). Note that the ship will be at the G + 00/22 arc at EP 00/22. It can be expected that the winds and seas will start picking up from the east to southeast between 12/21 and 00/22 and should be gale force or higher by 00/22 and thereafter. Likewise, by 00/22, the occluded front will be very close to our position. Rain or snow should start falling several hundred miles ahead of the front, so the weather will be quite sour by 00/22. By 12/22, the front should have gone onshore, but we will still be in a strong wind region (between the G + 12/22 arc and the 12/22 low position). Winds should become more southerly and showers will continue.

The work load can be lessened by using surface weather prognosis charts, but in case we are unable to copy them, we can fall back on the technique shown. Acceptable results are more difficult to obtain beyond 24 to 36 hours.

Finally, keep in mind that there are only three possibilities in regards to changes in the weather and the seas: (1) conditions will worsen; (2) conditions will stay about the same; (3) conditions will improve. The difficult part, naturally, is determining the magnitude of the changes.

EXTENDED OUTLOOKS

A forecast predicts such things as wind speed, wind direction, wave height, and so forth for a particular time and place. Similarly, the prog charts can be considered to be forecast charts up to about 48 hours ahead. Beyond 48 hours, it becomes increasingly difficult to make forecasts as we usually think of them and so broad generalizations are made about future conditions. The 72 hour extended outlook surface progs from the NWS/USCG and the Navy's (NPM) 72 hour surface progs and 72 hour 500 millibar progs properly fall into the category of outlooks rather than precise forecasts in predicting the future weather pattern.

Mentioned earlier was the fact that the weather pattern at 500 millibars is usually more accurately predicted than that at the earth's surface, so the 72 hour 500 millibar prog can be used to advantage by noting where the jet stream is along with the location of highs and lows. Using the 72 hour surface progs can also provide useful information. The strength of the lows and highs on the surface weather analysis can be compared to those on the long-range progs. How much they change and their locations shown on the prog charts can be in considerable error in some cases; but we can still draw conclusions about how the pattern is expected to change and be alerted to possible problems later on.

SECTION IV.

PUTTING IT ALL TOGETHER

Without question, there are many charts available for use in following North Pacific weather. It is best to use only those charts actually needed and to become proficient in their interpretation and not to be burdened down by too much detail. As mentioned earlier, the best results will be obtained if we receive charts on a regular basis and not just an occasional one here and there because a series of charts allows us to get the "feel" of the weather patterns, especially when we use forecasts and our own weather observations in conjunction with the charts. Figure 9 shows a suggested display of maps from station NPM that will give a very complete picture of the weather pattern for up to 72 hours ahead.

By using a bulletin board, a whole display of charts can be examined almost at a glance, and it also permits changes in the weather pattern to be easily picked out. As each new surface analysis is received, it is tacked over the one preceding it so that we can leaf back through the analysis charts to see how the pattern is changing. It is recommended that at least the past two or three day's worth of analysis charts be saved.

As each new prognosis chart is received, the previous version can be discarded. Compare the positions of highs, lows, ridges, and troughs with the older version before discarding it to see how the pattern is predicted to change in relation to the older chart. Progression of the weather pattern can be picked out using this method. It is possible to get by on fewer charts than are shown in the figure, but for extended outlooks to 72 hours, the 500 mb progs are very necessary. If you are in protected waters, the significant wave progs do not need to be copied. However, if you are in a bay that opens up to the open sea, you may still want to receive

SURFACE ANALYSIS	36 HR SIGNIFICANT WAVE PROG
36 HR SURFACE PROG	36 HR 500 MB PROG
72 HR SURFACE PROG	72 HR 500 MB PROG

FIG. 9. SUGGESTED WEATHER MAP DISPLAY USING STATION NPM CHARTS.

these charts because in-coming high waves may cause problems. Whether or not the horizontal weather depiction prog is copied depends on how important it is to you to have some idea about significant weather that may affect your area. It is a useful chart for seeing the predicted location of fronts and lows.

A similar display can be made up using charts from other stations. At the very least, a surface weather analysis should be copied twice a day along with the surface progs and wave charts. There may not be space enough to put up a map display on some smaller vessels, so clipboards can be used to hold the various charts that can be stowed out of the way when they are not needed.

WEATHER EXAMPLE I

The purpose of this example is to show the relationship between the surface map and the 500 mb chart. Figure 10 only shows part of the area covered by the actual charts that are transmitted.

Let us first examine the 500 mb prog shown in the bottom panel. The wind speeds are denoted just like they are on the surface charts through the use of barbed shafts. For example, the wind about 60 miles off the central Oregon coast is SW at 25 knots. Instead of using isobars to outline the weather pattern, height contours are used (solid lines), which are lines showing the elevation of highs, lows, ridges, and troughs above sea level. A ridge extends from the high located at 35N/165W toward the NNE over the Gulf of Alaska. This is a strong blocking ridge because of its extensive elongation. Another ridge lies north of the high center located at 22N/168E, but it has little elongation, and a jet stream at 50 knots and more blows from west to east. The closer the height contours are together, the stronger the wind will be just as was the case with isobars on the surface map.

A trough extends SW from the low center at 44N/138W. Note how this low is caught under the "curl" of the ridge. Lows in this pattern on the east side

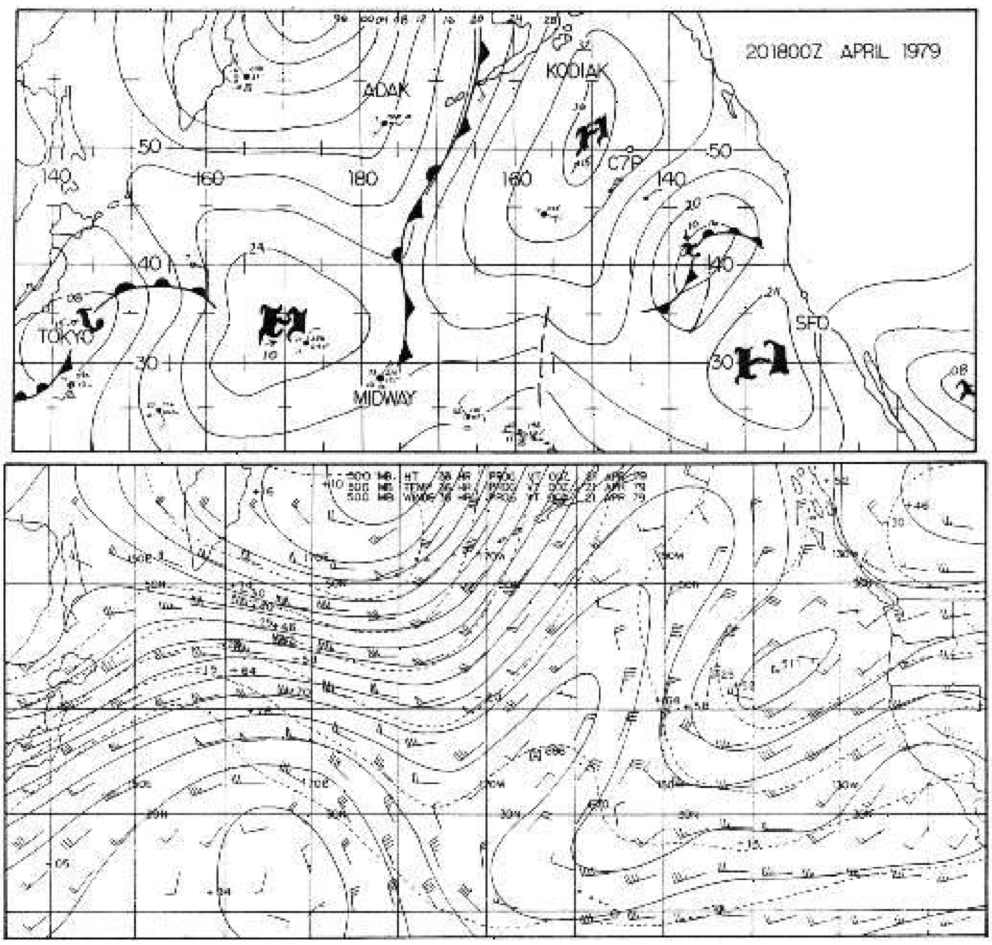


FIG. 10. NPM SURFACE ANALYSIS (TOP MAP) VERSUS THE 500 MB PROG (BOTTOM MAP).

of the ridge move rather slowly both at the 500 mb level and at the earth's surface. On the other hand, lows to the west of the ridge move rapidly in the west-east jet stream.

The height contours are drawn for every 60 meters of change and represent the elevation at which the pressure of 500 mb would be found. (The elevations are close to the actual geometric height, but not exactly. This is a point that is beyond the scope of this publication.) Consider the height contours in the region between 40N and 50N between 170E and 160E.

Contours in this area are labeled +34, +40, +46, +52, +58, +64, +70, and +76. To get the elevation, all we do is multiply each of these numbers by 10 and add the result to 5000. Thus +34 = 5,340 meters; +40 = 5,400 meters; +46 = 5,460 meters, and so forth. In a low, the elevations are less than those in a high. For example, the high at 35N/165W is found at an elevation of 886 (5,886 meters), and the low several hundred miles west of Oregon has a height of 511 (5,511 meters). Note that the elevations of the high and low centers do not have to be multiplied by 10 before they are added to 5,000 (or 4,000 or 6,000, depending on the depth of the low or height of the high). Whether you add 4,000 or 6,000 to the height will be obvious from the labeling on the contours. The 500 mb chart is very similar to a topographic map because the lows are the valleys in the weather pattern, and the highs are the mountain tops.

The temperature lines (isotherms) are shown by the dashed lines and are labeled in °C. We will not go into the effects of temperatures because this is a lengthy topic that is once again beyond the scope of this publication. Suffice it to say that the lowest temperatures are found in the lows.

The main features to look for in using the 500 mb prog chart are: (1) the location of ridges and troughs as surface lows deepen when they come under 500 millibar troughs; (2) the location of strong jet stream in which winds are 50 knots and higher; (3) changes in the jet stream by comparing the 36 hour prog with the 72 hour prog. Let us now examine the surface chart for 1800 GMT 20 April 1979.

Note that a large high pressure system dominates the Gulf of Alska. The front that lies along the western edge of the high will move very slowly eastward and weaken because a high of this strength will tear it apart. (A high of 1032 mb or greater over the ocean is a strong high.) Let's assume we are underway from Kodiak, Alaska to the vicinity of Unimak Pass in the Aleutians. The weather pattern looks fairly favorable for the next few days, but because we are on the western edge of the high and under a strong jet stream, it is not too likely that the good conditions will persist too long. We should look for lows to the west of us or anywhere where they might be moving to come under the jet stream that stretches from us to Japan. We can see from the 500 mb prog that the high at 22N/168E shows little ridging to block any lows. If we have the 72 hour 500 millibar prog, we could see if this was to remain so for the next three days.

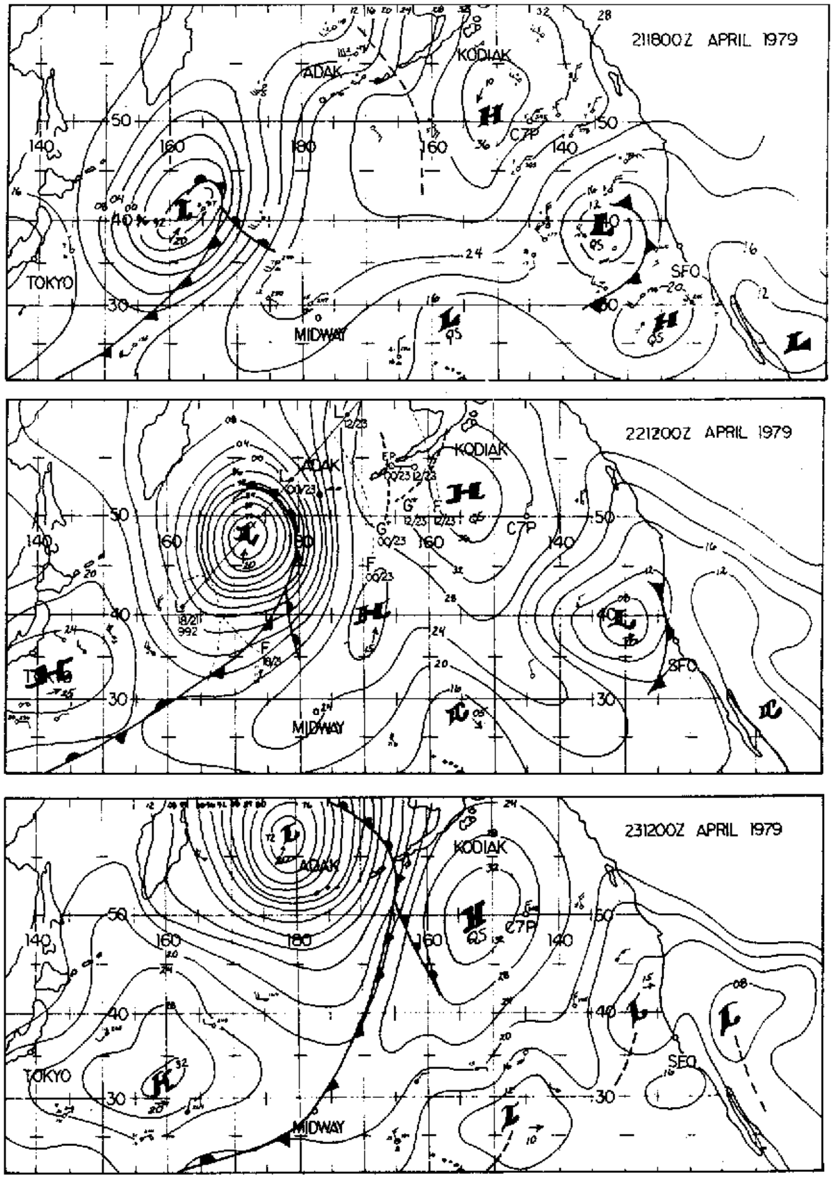
We note that the surface low southeast of Tokyo is moving NE at 15 knots. It is going to come under the jet stream and move toward us, and so we would be wise to keep copying the charts and follow its progress. Weather Example II shows what happened.

WEATHER EXAMPLE II

This series of charts shown in Figure 11 consists of NPM surface analysis (final) maps for 1800 GMT 21 April, 1200 GMT 22 April, and 1200 GMT 23 April 1979. We will use the technique of predicting the location of a low, weather front, and high wind area as outlined with the discussion for Figure 8.

The 1800Z 21 April chart (top panel) shows that the low that was near Tokyo 24 hours earlier is deepening and advancing NE at 20 knots. The central pressure has dropped from about 1006 mb to about 990 mb, but the high near 50N/150W has remained nearly stationary with a very high central pressure of over 1036 mb. Note how the isobars are getting closer together between 180W and 170E. This area of close isobars with associated strong winds is advancing toward us as we proceed toward Unimak Pass. The occluded front near 160W is dissipating as shown by the dashed lines. Winds are SSW 15 to 25 knots in our vicinity.

Let's assume our present course and speed will get us to within about 30 miles of Unimak Pass at 0000Z 23 April. The weather situation is expected to worsen, which is confirmed on the 1200Z 22 April analysis, for the storm has continued to deepen and is now at about 974 millibars at the center of low pressure. The region of gale force and higher winds that was just west of 175W is now at about 170W. We employ the techniques shown in Figure 8 and determine that gales will reach Unimak Pass about the same time we will. To avoid the uncomfortable ride, we speed up so that we will be through the pass before the high winds and seas arrive and will be in position to use the north side of the Aleutians as a lee against the southerly winds. Notice that the gales (heavy dashed lines labeled G+) will reach Unimak Pass at 0000Z/23 and be past 160W by 1200Z/23. The strong high in the Gulf of Alaska remains at over 1036 mb and has shifted slightly westward. Additionally, we predict that the occluded front will be near 170W at 0000Z/23 and past 160W at 1200Z/23. All in all, the weather situation looks pretty nasty, and we will have saved ourselves a rough trip by



(1800 21 April 1979 map)

(1200 22 April 1979 map)

(1200 23 April 1979 map)

FIG. 11. NPM SURFACE WEATHER ANALYSIS CHARTS FOR WEATHER EXAMPLE II. NOTE THAT ONLY PART OF THE AREA ACTUALLY COVERED BY THE TRANSMITTED CHARTS IS SHOWN.

speeding up to beat the storm. How good was our judgement?

Compare our predictions for 1200Z/23 with the actual analysis at 1200Z 23 April. We missed the position of the low center by almost 300 miles. This is not bad considering we used charts 18 hours apart upon which we based the speed and direction of movement. Had we used the speed and direction of the low shown by the arrow on the 1200Z 22 April analysis of NNE 20 knots, we still would have missed the location of the low center by about 240 miles. (This points out the importance of using charts that are within 12 hours of each other). We missed the position of the front by about 180 miles. However, we were almost exact in our location of the high wind area. Note that the isobars are closely spaced along the 160th meridian, which is where we predicted they would be at 1200Z 23 April. We can be satisfied with the results of our prediction because, after all, it was the location of the gales we were concerned about.

This example points out the importance blocking highs have. If we had been operating in the area east of the high pressure ridge in the Gulf of Alaska, we could have been confident that conditions would have remained pretty much the same from at least the 20th through the 23rd of April.

APPENDIX A
GLOSSARY OF TERMS

The following terms are often used on weather charts and in forecasts.

BACKING—Counterclockwise change in wind direction (e.g., change in direction from north to northwest to west; east to northeast to north, etc.).

COMPLEX LOW—A large area often more than 1000 nm across in which two or more low centers exist.

DEEP LOW—A rather subjective term used to describe the central pressure of a low center (usually when it is about 975 mb or less). Winds are strong gale force to storm force around the low.

DEEPENING LOW—A low in which the central pressure is decreasing with time. Winds would be expected to increase as the low deepens.

DENSE FOG—Fog in which visibility is less than ¼ mile.

DEVELOPING HIGH—A change in the weather pattern in which higher pressure is building up over an area.

DEVELOPING LOW—A change in the weather pattern in which lower pressure is forming over an area that is likely to result in a definite low center.

DISSIPATING LOW—A low center that is becoming weaker as the central pressure increases with time. Winds, in most cases, decrease; low expected to vanish.

EASTERLY WINDS—True wind direction from the northeast to southeast sector; used when the forecaster is uncertain about the exact wind direction, but is confident that it will come somewhere between NE and SE.

FEW SHOWERS—Low probability of precipitation in which a small number of showers will occur.

FILLING LOW—Low center in which the central pressure is increasing with time; not the same as dissipating low because the low may not necessarily vanish.

FRONT—Boundary zone separating two masses of air, one of which is colder than the other. Types of fronts: (1) warm front (warmer air overtaking colder air); (2) cold front (colder air overtaking warmer air); (3) occluded front (cold front overtaking warm front); (4) arctic front (special case of cold front in which air behind front is very cold, say less than 10°F); (5) stationary front (a front that is not moving). See Table III for winds and weather associated with moving fronts.

GALE—Sustained wind speed of 34 through 47 knots.

GALE WARNING—Special alert to mariners for sustained winds of 34 through 47 knots.

HIGH—An anticyclone, A weather pattern in which isobars at the center of the pattern are of higher than those further from the center. Winds are clockwise in the Northern Hemisphere.

HURRICANE—Severe tropical cyclone with winds higher than 65 knots. Winds are counterclockwise in the Northern Hemisphere and have been estimated at over 200 knots in the severest of hurricanes.

INTENSIFYING HIGH—Anticyclone in which the central pressure is increasing.

ICING—Accumulation of freezing water droplets on a vessel. Light (0.4 to 1.4 inches accretion in 24 hours); moderate (1.4 to 2.6 inches accretion in 24 hours); heavy (2.6 to 5.7 inches accretion in 24 hours); very heavy (5.7 inches accretion or more in 24 hours).

INSTABILITY LINE—Band of unstable air usually found ahead of a cold front that may develop into a squall line of thunderstorms. Usually 10 to 50 miles wide and several hundred miles long. Not all cold fronts have instability lines.

LINE OF CONVERGENCE—Area in the trade wind zone found between about 10° to 15° latitude north or south of the equator where the NE winds meet the SE trade winds from the Southern Hemisphere. Often called the Intertropical Convergence Zone or ITCZ. May also be used to denote any area in the tropics where winds from different directions meet. Weather often consists of heavy rain and thunderstorms.

LINE OF DIVERGENCE—Zone in the tropics where winds flow away from each other. Area should be free of rain or extensive cloudiness.

LOCALLY STRONGER WINDS—Conditions in which winds over many small areas too numerous to mention are expected to be higher than the general wind in the area covered by the forecast (e.g., locally stronger winds may occur in fjords and channels as compared to winds over the open waters).

LOW—Cyclone or depression. Weather pattern in which closed isobars at the center of the pattern are of lower pressure than those further from the center.

MODERATE LOW—A rather subjective term used to describe the indensity of a low; used when the central pressure is about 975 to 1000 mb. Winds generally less than about 40 knots.

NORTHERLY WIND—True wind direction from the NE to NW sector.

NUMEROUS SHOWERS—Frequent number of showers are likely over more than half the area covered by the forecast.

PATCHY FOG—Fog occurring in less than half the area covered by the forecast.

PERIOD—Time (in seconds) it takes for successive wave creasts (or troughs) to pass a fixed point.

PRESSURE GRADIENT—Difference in pressure between two points divided by the distance between them. The greater the difference in pressure between the same two points, the greater the wind. The closer the isobars are together on a weather map, the greater the pressure gradient.

RIDGE—Area of high pressure in which the isobars are elongated instead of circular or nearly circular (see Figure 3). Flat ridge: elongation of isobars is not great enough to prevent penetration of weather fronts through the ridge. Strong ridge: elongation of isobars is great enough to prevent weather fronts from penetrating the ridge. The concept of a ridge also applies to upper air weather maps that are made for heights over 5,000 feet.

SCATTERED (SCT) SHOWERS—Precipitation is expected to fall within about 30% to 45% of the area covered by the forecast.

SEAS—Combination of wind waves and swell making up the irregular surface of the sea.

SHEAR LINE—Narrow zone across which the wind direction changes rapidly.

SHORT WAVE—Term occasionally used in forecasts that may be considered to be a moving low, weather front, or high.

SIGNIFICANT WAVE HEIGHT—Average of the highest one third of the waves.

SOUTHERLY WIND—True wind direction from the SE to SW sector.

STATIONARY (STNRY)—Less than five knot movement of high, low, or front.

STORM—Low pressure system in which winds are 48 knots or higher.

STORM WARNING—Highest level of marine warning for storms that are not hurricanes or typhoons. Issued when winds are expected to be 48 knots or higher.

STRONG LOW or STRENGTHENING LOW—Low pressure system in which the winds are at least gale force or are likely to reach gale force or higher as the central pressure of the low drops.

SWELL—Waves that have left the wind fetch area where they were created and have become more rounded in shape and regular in period.

TROPICAL DEPRESSION—Cyclone that originates over the tropical ocean and may be the early stage of a hurricane or typhoon. Winds up to 33 knots.

TROPICAL STORM—More intense tropical cyclone in which the winds are 34 knots through 63 knots.

TROUGH—An elongation of the isobars around a low (see Figure 3). Inclement weather often occurs in a trough. This term is also applied to weather patterns found in the upper air.

TYPHOON—A hurricane in the western Pacific Ocean.

WEAK LOW—Low pressure system with winds less than gale force. Central pressure is usually above 1000 mb.

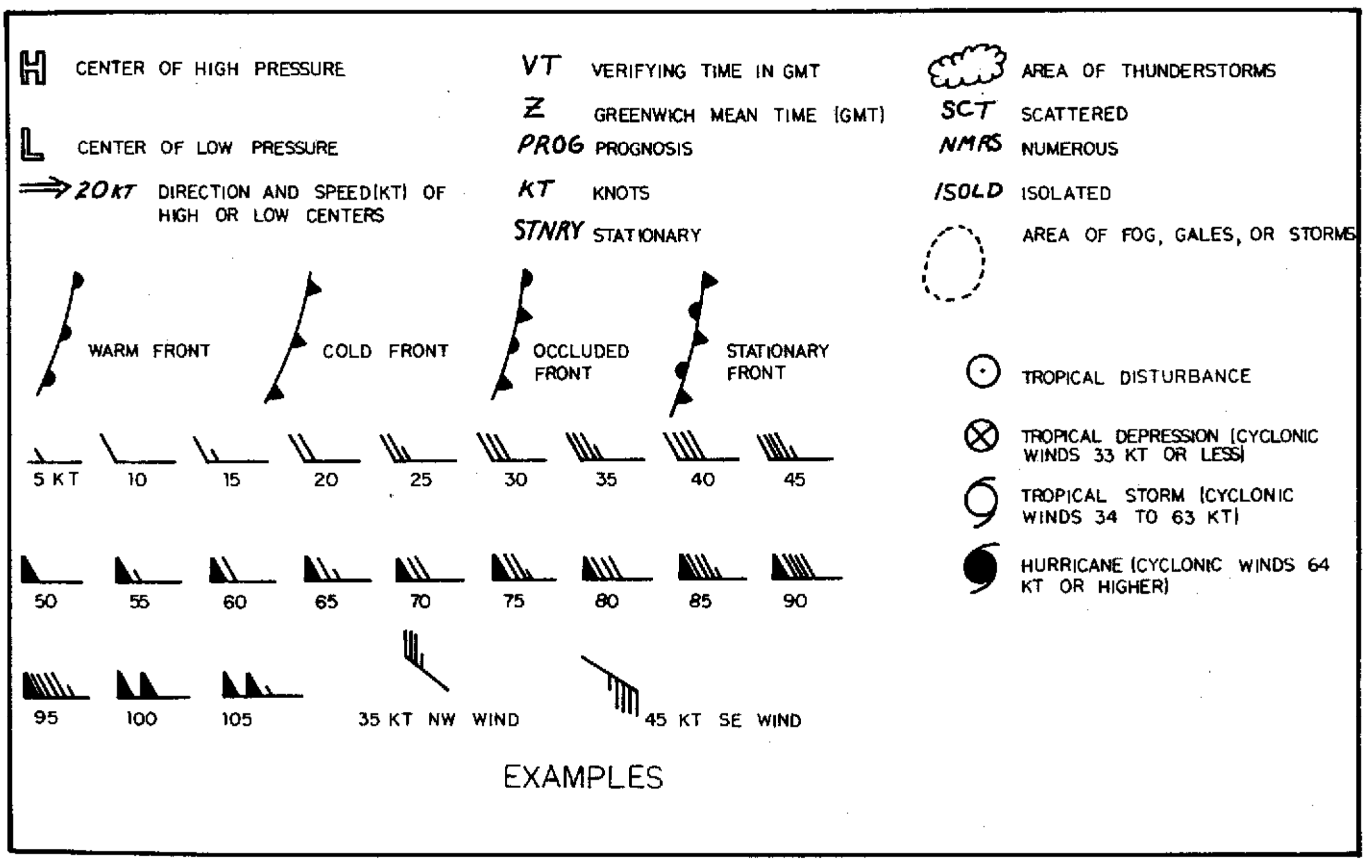
WEAK FRONT—Weather front that has winds less than about 20 knots and which is disappearing with time. A strong front may become a weak one as it tries to push through a stationary ridge of high pressure. Some cloudiness and light precipitation may still occur.

WEAK HIGH—High pressure system that is incapable of keeping weather fronts from passing through it. Central pressure of a weak high will usually be 1020 mb or less.

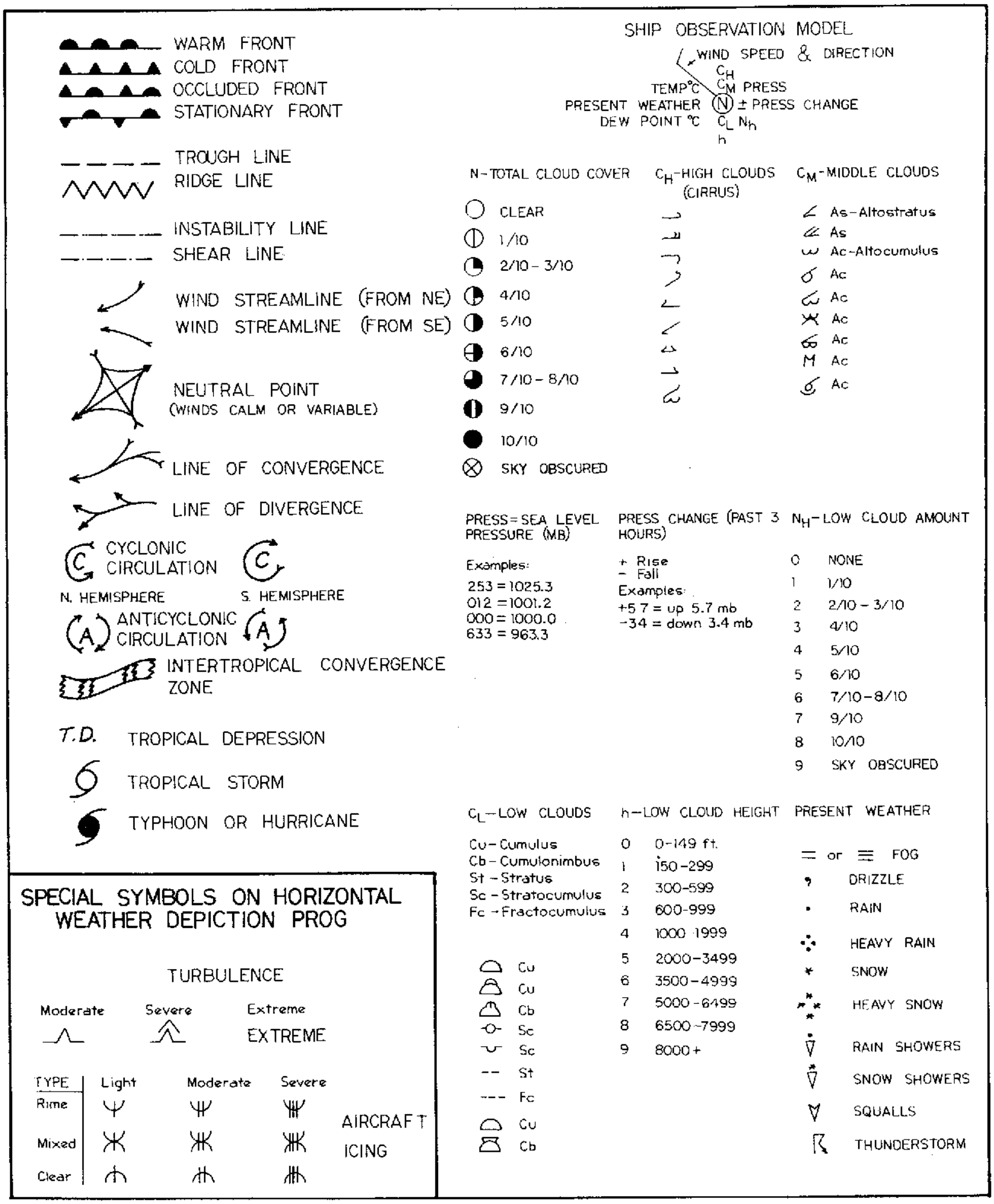
WESTERLY—True wind direction from the NW to SW sector.

APPENDIX B

Symbols Used on Surface Weather Maps



These symbols are used on the surface weather maps made by the National Weather Service and broadcast from stations NMC (Pt. Reyes, CA) and NOJ (Kodiak, AK). Wind directions are *true,* not compass directions.



These symbols are used on the surface weather maps made by the U.S. Navy and broadcast from stations NPM (Pearl Harbor, Hawaii) and NAM (Norfolk, Virginia). Additional symbols used on the horizontal weather depiction map are shown in the inset. The Navy uses the same wind barb symbols as used by the NWS.