U.S. NAVY
MARINE CLIMATIC ATLAS OF THE WORLD
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EUROPE

The first section provides a seasonal overview of the weather for open waters. The second section deals with important weather-related features. The remainder consists of a detailed climatological summary by region and stresses weather features which are of particular concern to the mariner.

NORTH SEA-BALTIC SEA CLIMATE

WINTER - Winter in the North Sea-Baltic Sea region is forbidding. A seemingly endless march of strong Atlantic storms bring rain or snow and gales, while long periods of bleak, drizzly weather accompany the weaker storms that form along slow-moving fronts. This procession is occasionally interrupted by frigid high pressure systems that can cause treacherous fogs in addition to low temperatures. Coastal residents view winter as a long stretch of gloomy, drizzly days with a few spells of bright cold weather. For mariners it is a difficult season.

The North Sea-Baltic Sea area is affected by the frequent winter storms that move between Greenland and the British Isles, and the large storms that form near Iceland and remain stationary for several days. Both of these systems help make up the climatological Icelandic Low that appears on average monthly pressure charts. Centered between Iceland and Greenland, this winter Low dominates the North Atlantic, including the North Sea-Baltic Sea, north of 40 degrees N. Several situations that cause winter weather problems are examined below. The winter storms that move between Greenland and the British Isles are often large and intense. In advance of these systems, the flow over the region is generally southwesterly, sometimes reaching gale force and often accompanied by widespread light rains. A slow-moving front that separates this southwesterly flow from a cold northwesterly flow to the rear of the cyclone, provides a likely area for a secondary storm or wave to form. This can occur to the west of the English Channel or in the North Sea. These atmospheric waves produce shifting gusty winds, precipitation and sharp temperature drops. A wave that forms in the Skagerrak can be even more trouble. This "Skagerrak Low" develops as a secondary system with the parent storm decaying in the Norwegian Sea. The Skagerrak storm usually deepens very rapidly and becomes the dominant system. It brings bad weather and often gales to the Baltic area. The storm usually moves toward the northeast or southeast. This development is most likely in winter and spring when the blocking action of the Siberian High is most effective in slowing down fronts. A stalling low in the Norwegian Sea and a high east of France generates a strong northwesterly flow over the North Sea and southern Baltic. This flow is often accompanied by rain or snow squalls.

Atlantic storms can also move across the region from the northwest through southwest. Lows from the west and northwest usually bring strong, shifting winds and rain or snow. Those from the southwest are often accompanied by drizzle and fog. Occasionally a low is situated off France with a high in the Norwegian Sea. This causes a mild southeasterly flow and showers. However, if an intense low develops over north central Europe it can pull in cold air from the Greenland-Spitzbergen region. Showers and snow squalls develop as cold air streams southward over warmer seas.

The northern Baltic Sea and the Gulfs of Finland and Bothnia are somewhat sheltered from Atlantic storms by the Scandinavian mountains. A southwest or southerly flow into the area brings fog and drizzle. Westerly winds are dried out by their mountainous journey. This eastern region is more continental than maritime. Often cold dry air builds up over the continents and ice. This air can stagnate and cause very low temperatures on these coasts. If it spreads southward and westward over open seas it can trigger snow showers from the southern Baltic to the North Sea. When a High develops or moves over Scandinavia and forces storms to move across France, an easterly flow is set up over the area and can persist. Such an occurrence in 1947 brought easterly winds for 31 straight days.

One of the most startling changes in the weather occurs when a large frigid high from the Soviet Union moves into the area. It can dominate weather for weeks at a time. Skies clear, temperatures drop sharply and winds slacken. In addition to the frigid conditions, the coastal atmosphere becomes ripe for extensive radiation fog formation. This fog can choke channels and coasts throughout the area.

Over open waters in this region, winter winds, in general, blow from the southeast through northwest. Southwest winds are the most common. Each area has its own peculiarities due to topography and storm position.

In the North Sea and English Channel, westerly winds are often as frequent or more so than southwest winds. This is especially true from November through January. Over the eastern North Sea, northwest winds are common, particularly early and late in the season. In fact, around the entrance to the Skagerrak, northwesterlies are the most common wind in December and from February through September. Elsewhere in the North Sea and English Channel, northwesterlies are an important secondary wind and most likely to be encountered from November through February. Southeasterlies over the entire North Sea and southerlies in the western half are frequent in December and January. Easterlies are often encountered at the entrance to the Skagerrak from January through April, particularly in February.

In the Skagerrak-Kattegat-Sound area southwesterlies are most frequent south of the Skagerrak where they are at their annual peak from November through January. Westerlies are slightly more frequent in the winter over the Skagerrak and in late winter to the south. Southerly winds are also often encountered from November through February. In the Kattegat, southeasterlies are frequent in January. East winds are not too frequent, but in the Sound and the entrance to the Baltic, their frequency increases as winter wears on.

Easterlies in the southern Baltic and northeasterlies over the entire Sea also increase infrequency toward late winter. Southwesterlies and westerlies are again the most important winds. Southwesterlies are at an annual peak from November through January as are westerlies in January; around Gotland westerlies are at a peak from November through January although they are still second to southwesterlies. Two important secondary winds are southerlies and northwesterlies. Southerlies are very common from the Gulf of Danzig to the northern Gulf entrances from November through January. Northwesterlies are frequent over the entire Baltic from November through February, particularly in February.

Gulf of Finland waters are subject to a lot of southwesterly and southerly winds from November through February. These winds along with southeasterlies are at a peak in December and January. West winds are also an important secondary wind in the Gulf while northeasterlies become more common as winter turns to spring.

Average winter wind speeds range from about 14 to 20 knots over the North Sea-Baltic Sea region. Southerly and easterly winds, while not always as frequent as others, are usually strong and average 17 to 24 knots during the winter. Southwest and west winds speeds are also in this range. On the average strongest winds and most frequent gales will be encountered in the North Sea, western English Channel and Skagerrak. Lightest winds are usually observed in the Strait of Dover and Kattegat-Sound area. From November through February gales occur 12 to 14 percent of the time in the central North Sea, the entrance to the Skagerrak and the western Channel. In other regions, they are recorded 7 to 10 percent of the time. Gales most commonly ride southeast through northwest winds, coinciding with the prevailing flow. Near the North Sea entrance to the Skagerrak winter gales often occur with east and southeast winds. In the extreme they have lasted up to 60 hours at one time. Gale-force winds from 34 to 47 knots are most common. Speeds of 48 knots or more are uncommon; they occur about 1 to 3 percent of the time in the exposed seas, including the Gulf of Finland, from December through February. The occurrence of extreme winds is most likely in winter. In a 5-year mean recurrence interval, extreme speeds range up to 80 knots in the central North Sea and a value of 115 knots can be expected on the average of once in every 100 years in this same region.

During December, precipitation falls about one-quarter of the time over northern and central North Sea waters. Almost all of this is light rain and drizzle. Snow occurs less than 5 percent of the time for most of the winter in these waters. During February and March, snow occurs just a little more than 5 percent, particularly near the entrance to the Skagerrak. In these waters, precipitation continues to be as frequent in January (25 percent). Elsewhere, in northern waters, it can be expected 15 to 20 percent of the time in other winter months. Frequencies decrease slightly to the south where peak frequencies occur in late fall. In these waters precipitation can be expected 12 to 16 percent of the time. Snow is rare, as reflected by the temperature range. Coldest temperatures are usually found in eastern waters. Here temperatures in February, the coldest month, range (90 percent of all observations) between 30 degrees and 45 degrees F. To the west and south, this February range is between 34 degrees and 47 degrees F. Eastern North Sea waters are not only the coldest and rainiest they are also the cloudiest. Cloudy skies (cloud cover greater than or equal to 6/8 prevail 55 to 65 percent of the time, while clear skies (cloud cover less than or equal to 2/8 can be viewed 10 to 18 percent of the time. Elsewhere cloudy skies can be expected about one-half of the time while clear skies occur 15 to 25 percent of the time. Visibilities are at their best in late fall and early winter over open waters. In seas that land fogs can reach, like the extreme southern North Sea, visibilities can get quite poor. In general over open waters visibilities drop below 2 miles 4 to 10 percent of the time; February is the worst month. In waters closer to shore these frequencies range up to 15 percent, particularly in late winter. Visibilities over the eastern half of the English Channel are an example of the influence of land fog. In February, visibilities are below 2 miles nearly one-quarter of the time. The less sheltered western end suffers these conditions just 10 percent of the time in February and about 6 percent at other times. The

Dover Strait region is consistently the worst area throughout the winter. One condition for land fog formation is clear skies. These are observed most often in February over the eastern Channel when they occur nearly one-quarter of the time. In the west, February is also the best winter month as clear skies occur 18 percent of the time. Skies are cloudiest in January when cloudy conditions can be expected nearly one-half the time. Other winter months are just a little less cloudy. From these cloudy skies, rain and drizzle fall 12 to 20 percent of the time. Precipitation is most likely in December and January, particularly in the western Channel. While snow is rare in the Channel, hardly a winter goes by without at least one occurrence. The lack of snow is mainly due to temperatures which stay above freezing most of the time. The warming influence of the North Atlantic is responsible and is also responsible for an east-west temperature gradient. Temperatures, on the average, are 5 degrees F warmer, particularly minimums. There is very little within-season variation. In general, winter temperatures in the eastern Channel range (90 percent of all observations) between 35 degrees and 52 degrees F. In the western Channel, the range is between 40 degrees and 55 degrees F. North Atlantic winds lose some of their moderating ability by the time they reach the Skagerrak. Temperatures from the Skagerrak to the entrance to the Baltic, are coldest in January and February when they range between about 25 degrees and 42 degrees F. These temperatures indicate the possibility of snow. Snow is most likely in January and February. In the Skagerrak, it occurs 5 to 10 percent of the time and is most likely near Oslofjord. Elsewhere, snow falls between 5 and 10 percent of the time. The frequency of precipitation reaches an annual peak in December and January when it occurs 15 to 20 percent of the time; it is most likely in the Kattegat and The Sound. By February, these frequencies run between 9 and 14 percent, increasing toward the south. Visibilities are bad in January when land fog, rain and snow drop visibilities below 2 miles 13 to 17 percent of the time. In the Kattegat they are a little poorer in December and in the Sound a little poorer in February. In December and January, cloudy conditions (cloud cover greater than or equal to 6/8) cover these waters 55 to 65 percent of the time. Clear skies (cloud cover less than or equal to 2/8) are seen 15 to 20 percent of the time. In February, skies brighten considerably. Clear skies can be expected 20 to 35 percent of the time; they are most likely in the Kattegat. Cloudy skies are observed a little less than one-half the time in the Kattegat and Skagerrak and more than half the time in the Sound and to the south.

In the navigable part of the Baltic, winter skies are cloudiest in December, when cloudy conditions can be expected 60 to 65 percent of the time and clear skies just 10 to 20 percent. Sky conditions improve slightly in January and February. Under gray skies the frequency of precipitation reaches an annual peak in southern waters in December. It can be expected about 15 percent of the time. In the seas east of Sweden, precipitation occurs more than 20 percent of the time in January; 5 to 10 percent of the time it falls as snow. In the mostly un-navigable Gulfs snow occurs up to 25 percent of the time in January and February. In southern waters snow can be expected around 5 percent of the time. Temperatures in the Baltic seas are coldest in February when they range (90 percent of all observations) between about 25 degrees and 41 degrees F. In the Gulfs, this range is closer to the 15 degrees F. Western Baltic visibilities remain fairly good throughout the winter. They drop below 2 miles about 7 percent of the time. This is also the case in other sections of the Baltic until February when frequencies increase to a little more than 10 percent. Visibilities in the Gulfs are poorest in January and February.

SPRING - While storms weaken in early spring, the center of storm activity shifts over the North Sea and southern British Isles. This results in a greater number of weaker lows moving directly across the region bringing lighter but more variable winds. By May cyclonic activity is still weaker and storms tend to move across the northern North Sea and southern Scandinavia into the Gulfs of Bothnia and Finland. Despite this activity skies brighten, precipitation decreases and winds are lighter.

Over the entire region springtime brings variable winds. In general, there is an increase in the frequency of winds from the north through east and a slight decrease in the frequency of southwest and west winds. Also wind speeds begin to drop. Gales are encountered less often.

Over the North Sea, north and northeast wind frequencies increase dramatically in early spring and remain influential into the early summer. Northerlies are more frequent and are stronger by an average of 2 to 3 knots. In northern and central North Sea waters southeasterlies and southerlies are influential spring winds, particularly around the Moray Firth where this influence prevails through the summer. Southeasterlies are among the strongest spring winds. These increases in the central and northern waters, correspond to a dramatic drop in the frequency of west and southwest winds particularly in April and May. Near the entrance to the Skagerrak, northwesterly winds prevail through the summer. Strongest winds in these waters are from the northwest and east. Easterly winds, infrequent everywhere else, are important near the Skagerrak entrance. Off the Federal Republic of Germany (West German) and west Denmark coasts winds from the southwest through north are the most frequent in spring.

Northeasterlies increase dramatically in the English Channel and in April are the strongest winds. From the Strait of Dover to the southern North Sea their influence lasts through September. Despite a dip in frequencies, southwest and west winds remain at or near the top in both frequency and strength. Northwest winds are an important feature at the western end of the Channel while easterlies are common in the central Channel in spring.

In the Skagerrak-Kattegat-Sound area westerlies remain the most frequent winds despite a drop in frequencies. They are among the strongest winds. Wind speeds are usually highest in the Skagerrak. In the Skagerrak and Kattegat, southwesterlies fall off in spring but remain among the most frequent winds. East and northeast winds are common to the Skagerrak, particularly in April and May. In April, northeasterlies tend to be very strong in these waters. Southerly winds are frequent in the Kattegat, particularly in May while southeasterlies are important in March. In The Sound and Baltic entrance, easterly and northeasterly winds are frequent in the spring. By April northwest winds become frequent and strong. In the waters to the north, northwesterlies become significant by summer.

In the Baltic Sea, northeasterlies battle for control with westerlies in the south and southwesterlies around Gotland. Northeast winds are most influential in May when southwest and west winds are at their weakest. Easterlies become a primary spring wind in the south but do not usually carry speeds as high as westerlies and northeasterlies. In general, wind speeds remain highest in the western waters. In the southern Baltic, the east and northeast influence fades by early summer. However, around Gotland, northeasterlies last through August. In the waters between the Gulf of Danzig and the entrances to the Gulfs of Finland and Bothnia, northerlies increase significantly in April and become strong secondary winds. Southerlies are a primary wind in these waters in spring. Strongest spring winds are generally out of the north, northeast and southwest.

Two dramatic changes take place in spring winds in the Gulf of Finland. From February to March northeasterlies become a primary wind although southerlies still dominate. In April, westerly and southwesterly winds become most frequent and remain so until August. In late spring, east winds become frequent in the Gulf. No one wind direction carries particularly stronger speeds in spring. May is the first month of wind data in the Gulf of Bothnia. Two directions are dominant-north and south. Wind speeds are highest from the north and northwest.

Spring gales are confined to no one direction and continue to follow the rule of riding in on the most frequent wind directions. Since northeast winds become important in spring, gales out of the northeast are frequent over open waters. They also come from the south through north, too. Southeast gales can be encountered in the Moray Firth and easterly gales cause trouble at the North Sea entrance to the Skagerrak. The most notable feature in spring is the decline of gale frequencies; a trend that continues into late spring and early summer. The biggest drop usually occurs in April when gales will not be encountered more than 4 percent of the time anywhere, on the average. If you are looking for trouble gales are most frequent over the eastern North Sea and in the Skagerrak. They are least frequent in the eastern English Channel and in the waters around Gotland.

During spring, temperatures rise, skies clear, rain slackens, but fog increases.

North Sea visibilities are at their worst in spring. They fall below 2 miles about 8 to 16 percent of the time. Relatively warm air flowing over cool waters produce sea fog, which over western waters continues to form right into summer. Near the North Sea entrance to the English Channel, land fog continues to form and adds to the fog problem. Land fog is aided by clear skies (cloud cover less than or equal to 2/8), which occur 27 to 32 percent of the time, in these southern waters. Also cloudy skies (cloud cover greater than or equal to 6/8) are least frequent occurring about 30 to 40 percent of the time. Elsewhere, cloudy skies blanket the seas 40 to 50 percent of the time and skies are clear about 15 to 30 percent of the time. Clear skies are most likely near the entrance to the Skagerrak. Clearing skies and longer days give temperatures a chance to rise and they continue this upward trend until midsummer. In March, the range of temperatures (90 percent of all observations) runs between 34 degrees and 46 degrees F in eastern waters and from 36 degrees to 50 degrees F in the west and south. By May this range is 40 degrees to 55 degrees F in the north and between 45 degrees and 60 degrees F in the south. As these temperatures would indicate, snow is infrequent by March. Precipitation in general, declines from its peak winter frequency to a minimum in spring. It is most frequent in northern waters, occurring about 10 to 20 percent of the time and least frequent in the south, where it is observed 8 to 10 percent of the time. By May, the North Sea frequency range is 8 to 12 percent.

Like the southern North Sea, the English Channel is susceptible to two types of fog and visibilities drop below 2 miles from 9 to 18 percent of the time. Highest frequencies occur in and around the Strait of Dover, where frequent clear skies aid land fog formation. Clear skies in the Channel occur around 25 percent of the time in March and about 30 to 35 percent of the time in May. The frequency of cloudy skies drops from 35 to 40 percent in March to 30 percent by May. Precipitation is infrequent in the Channel and occurs 10 to 12 percent of the time in March; this drops to 6 to 9 percent by May. Rain is most likely in the western Channel. Temperatures in the Channel are usually milder toward the west, particularly in early spring. In March, temperatures range from 36 degrees to 51 degrees F in the east and 41 degrees to 54 degrees F in the West. By May, there is little difference and the range of temperatures (90 percent of all observations) runs between 45 degrees and 60 degrees F.

From the Skagerrak to the southern Baltic Sea, visibilities improve as summer approaches. Fog drops visibilities below 2 miles 10 to 20 percent of the time in March and just 3 to 10 percent of the time in May. Fog is most likely in the entrance to the Skagerrak, particularly in March and April and the occurrence is dramatically reduced in June. In the Kattegat, this

reduction takes place in May. March is the most treacherous month from the Sound to the Gulfs of Finland and Bothnia while by April and May fog becomes infrequent. In addition to improving visibilities, skies also become less cloudy in spring. From the Sound to the Baltic, a sharp decrease in cloud cover is noticeable in May. Clear skies (cloud cover less than or equal to 2/8) are observed 40 to 50 percent of the time in May as compared to 25 to 35 percent in April. Cloudy skies (cloud cover greater than or equal to) blanket the area 25 to 30 percent of the time in May compared to 40 to 50 percent in April. The skies around Gotland are the clearest. This trend is also apparent in the Gulfs of Finland and Bothnia. In the Kattegat and Skagerrak, sky conditions make their most dramatic improvement in February and continue good into the summer. Skagerrak skies improve more slowly than those of the Kattegat, but remain clearer until later in the summer.

Clearing skies and increased daylight bring pleasant temperatures. From the Skagerrak to the southern Baltic, March temperatures range (90 percent of all observations) from 30 degrees to 45 degrees F while in May this range is 42 degrees to 60 degrees F. The Kattegat is often slightly colder in March and slightly warmer in May. This reflects its continentality and the change from winter to summer. In the Baltic Sea, where coldest temperatures are usually east of Sweden, the temperature range increases from 28 degrees to 43 degrees F in March to 40 degrees to 57 degrees F in May. The temperature range in the Gulfs of Finland and Bothnia increases from the upper teens to the low 40's in March to 36 degrees to 55 degrees F in May. In general, the Gulf of Bothnia is the colder of the two. Snow in these Gulfs can be expected through April. Everywhere else, April snows are rare. In March, Gulf snows occur 10 to 15 percent of the time and in the Oslofjord it occurs about 10 percent of the time. Elsewhere snow is uncommon. Precipitation is usually least likely in spring or early summer. From the Skagerrak to the southern Baltic, March frequencies drop below 10 percent. In April, accompanying a slight increase in storm activity, frequencies pick up slightly, but fall to March levels again by May. In the rest of the Baltic and in the Gulfs of Finland and Bothnia, precipitation is least likely in May and June.

SUMMER - Summer storms are most often weak. Fronts move through unimpeded so that cloud and shower activity is confined to a narrow band. This results in rapid clearing. The storms are most active to the west and far north of England. Some move over northern Scotland, across Norway and Sweden and into the Gulfs of Finland or Bothnia. Others, particularly in June, move from southern Europe northeastward to the Gulf of Finland. Shallow lows may develop over the Baltic Sea and drift northward. High pressure systems from the Atlantic sometimes settle in, bringing fine summer weather to the region.

North Sea summer winds, like those of winter, blow mainly from the south-west through northwest. However, in addition to being weaker, they are altered somewhat by the land-sea breeze effect which extends out even over open waters in this region. This effect is most noticeable when pressure gradients are weak. Over western waters a night breeze will blow off the land usually from the southwest through northwest. After sunrise, breezes become variable and confused. Gradually, as temperatures begin to climb, winds start to blow toward land. By afternoon, a breeze from the northeast through southeast takes control. By late afternoon, the sea breeze dies down and the flow again becomes variable. The afternoon disruption of the general westerly flow is noticeable clear across the North Sea. A southeasterly flow toward the Norwegian coast is evidence of a sea breeze near the entrance to the Skagerrak. Farther south, a northerly sea breeze affects open waters off the West German coast. In extreme southern waters, northeasterly sea breezes are common. The frequencies of these sea breezes may not be great but they are predictable in absence of a strong prevailing flow.

In the western North Sea, southeast through northwest winds are the prevailing flow during the summer. Southeasterlies and southerlies are the most important near the Moray Firth and in July northwesterlies also become frequent. Near the Firth of Forth, southwest and west winds prevail with north winds frequent in early summer and south winds later in the season. Gales in these western waters occur less than 2 percent of the time from May through August and winds from the southwest through northwest average 12 to 14 knots. In the eastern North Sea northwest winds are common; near the entrance to the Skagerrak they are the most frequent. West and southwest winds are also important, particularly off the West German coast. Northerlies are of secondary importance and near the Skagerrak easterlies remain influential through June. Although this is the windiest part of the North Sea, gale frequencies remain below 2 percent from May through August. Over eastern seas, northwesterlies are strongest; they average about 16 knots. In the southern North Sea, southwesterlies are most frequent all summer long. Winds from the west through northeast are also common. West winds become particularly important during July and August. Gales in these waters occur less than 1 percent of the time from May through July and just over 1 percent in August. Southwesterlies are the strongest and average 13 to 14 knots.

Summer winds in the English Channel are most frequently out of the west and southwest. Northwest winds are also common, particularly in July and August. The land-sea breeze effect is important and sea breezes often strengthen existing flow. The effect is least important in the more exposed western Channel. Around the Dover Strait northeast winds are frequent and reflect the sea breeze influence. In these waters when prevailing winds are light, northeasterlies and easterlies become much more frequent during the afternoon while the frequencies of westerlies and northwesterlies diminish. In the central Channel, when pressure gradients are weak, northerly winds are frequent in early morning, but

practically nonexistent in afternoon. The pure sea breezes will come from the east, or if there is an existing flow, the sea breeze will strengthen winds from the south through west and alter northwest through northeast winds. In the western Channel the sea breeze influences winds when the flow is very light. On these infrequent occasions, there is a reversal as easterlies take over from the more normal southwesterly flow.

The southwest-westerly flow remains the prevailing flow throughout the summer. Around the Strait of Dover southwesterlies are slightly more frequent while to the west, winds blow more out of the west. Northwest winds are also common, particularly in the central and western Channel. Gales occur less than 2 percent of the time from May through September in the western Channel and from April through September elsewhere. They occur less than 1 percent of the time from May or June through August. Strongest winds are from the southwest at an average of 12 to 14 knots.

From the Skagerrak to the southern Baltic Sea, westerly winds prevail during the summer. Southwesterly and northwesterly winds are also common. Gales are uncommon and occur less than 2 percent of the time from about May through July. Elsewhere gales become more common in August and occur up to around 4 percent. Just north of the Gulf of Danzig, gale frequencies increase to 3 percent in July and to more than 4 percent by August. Strongest winds are from the west and blow at an average of 13 to 17 knots. In general, they become increasingly stronger as summer wears on. West winds are strongest in the Skagerrak all summer and in the southeast Baltic in August.

The land-sea breeze effect is complex in these waters and is most apparent in the western part of the Baltic. Here the sea breeze boosts the already prevailing southwest and west flow. When conditions are right, northwest and north land breezes are observed at night. The sea breeze effect also boosts the normally prevailing flow to the east of these waters. Throughout the Skagerrak, Kattegat and The Sound regions northwest winds are most likely during the afternoon, particularly when pressure gradients are slack. In the Skagerrak there is also an afternoon increase in the frequency of westerly and northerly flow which often results from an alteration of prevailing light southwest winds. In the Kattegat, westerlies if not strong can be altered by the sea breeze as northwest and north winds become more common. In The Sound northeast and southwest winds are less common in the afternoon while southerlies, northerlies and northwesterlies increase in frequency.

In the Baltic, east of Sweden, southwest winds prevail during the entire summer and are in fact bolstered by the sea breeze. Southerly winds are also more common in the afternoon and, if pressure gradients are weak, a sea breeze often develops out of the northeast. Northerly and westerly winds are also common in these waters, particularly at night and in the early morning. Gales occur less than 2 percent of the time from April through August and less than 1 percent of the time from May through July. Winds from the west, southwest, and north are usually the strongest, averaging 11 to 13 knots.

Winds in the Gulf of Finland are often out of the west in June and July and southwest in August. Easterlies and northeasterlies are common also. Westerly winds increase significantly during the day as a sea breeze may run the length of the Gulf. An existing easterly flow may also be bolstered by the sea breeze effect. Land breezes are most apt to flow from the south. Gales in the Gulf of Finland are rare. They occur less than 1 percent of the time from April through July increasing to just over 1 percent in August. In June and July, strongest winds are out of the southwest and west at an average 10 to 12 knots. In August northeast winds average 14 knots.

The Gulf of Bothnia maintains its mainly north or south flow throughout the summer. Northeast and northwest winds are also quite common. Southerlies are bolstered somewhat by the sea breeze effect while northwesterly and northerly winds are more frequent during the night. Gales are rare until September. Strongest winds average 10 to 13 knots. In early summer, these are from the northwest through northeast while by August all winds blow in this average range.

Summer is a nice season over most of the North Sea.

Precipitation is infrequent, although often showery, skies are mostly clear or partly cloudy, temperatures are mild and visibilities are good. The worst conditions are found in the northwest. Visibilities drop below 2 miles, mostly in sea fog, about 10 to 14 percent of the time near the Moray Firth and 8 to 10 percent of the time near the Firth of Forth. Rainy weather can be expected 10 to 16 percent of the time in these waters; it is most frequent in August. Clear skies (cloud cover less than or equal to 2/8) which were prevalent in spring, occur infrequently and cloudy skies (cloud cover greater than or equal to 6/8) are observed nearly one-half of the time. The temperature range (90 percent of all observations) in July and August is from about 50 degrees to 63 degrees F. Conditions improve markedly to the south and east. Temperatures warm up a couple of degrees in central waters and in southern waters; the August range is 57 degrees to 68 degrees F. This indicates that only 5 percent of the time do temperatures get above 68 degrees F or below 57 degrees F. Warmer temperatures are not only the result of more southerly latitudes but of less cloudiness. Clear skies are enjoyed 20 to 30 percent of the time and skies cloud over about 30 to 40 percent of the time. Rain is also less frequent, particularly in southern waters where it occurs about 5 percent of the time in June. June is usually the month with the least frequent rainfall over the North Sea and the range is from 5 to 10 percent, increasing northward.

Frequencies increase in July and August, as do rainfall intensities, and by August, rain can be expected from 9 to 16 percent of the time. Fog near the Skagerrak entrance reduces visibilities below 2 miles about 5 to 8 percent of the time. In the southeastern North Sea these figures are even lower and reach a minimum of less than 4 percent in August-the same time a minimum frequency of 7 percent is reached in southern waters. English Channel visibilities also improve throughout the summer. The frequency of visibilities below 2 miles ranges from 13 to 15 percent in June and 8 to 10 percent by August. Best conditions are usually found in the open western Channel and worst conditions in the central waters. Precipitation frequency falls to an annual minimum of 6 percent in June except in the west where a minimum of 8 percent occurs in July. Frequencies increase in late summer as do amounts. Channel skies in summer are equally likely to be clear, cloudy or partly cloudy. The very slight east-west temperature gradient (warmer temperatures in the western Channel) of early summer disappears and by mid-summer the temperature range is 57 degrees to 68 degrees F over the entire Channel.

From the Skagerrak to the Baltic, summer is an excellent season. Visibilities are fantastic, skies are mostly clear, rain is brief and infrequent and temperatures are pleasant. In the Skagerrak, visibilities are good from June through August, when they drop below 2 miles just 5 to 7 percent of the time. In June, the frequency of rain falls to a low of about 5 percent. Clear skies are observed 35 to 40 percent of the time with cloudy conditions occurring less than 30 percent of the time. The temperature range in the Skagerrak is 50 degrees to 66 degrees F in June and 55 degrees to 68 degrees F in mid-summer. The Kattegat and The Sound waters are slightly more continental than the Skagerrak. For example, mid-summer temperatures range from about 56 degrees F to 72 degrees F. Also showers are more apt to occur in these waters and frequencies range from 10 to 15 percent. Another indication is the greater frequency of partly cloudy skies, particularly in the Kattegat, as summer type convective clouds are frequently observed. Perhaps the biggest indication of continentality is the extremely good visibilities encountered in the Kattegat, The Sound and the southern Baltic Sea. The frequency of visibilities less than 2 miles is less than 5 percent from June through September. In August and in some places in September visibilities less than 2 miles occur less than 2 percent of the time in these waters.

These excellent visibilities extend into the northern Baltic and the Gulf of Finalnd, particularly in August and September, and into the Gulf of Bothnia in July and August. Rainfall frequencies remain below 10 percent in the southern Baltic with the least activity in June and August. However, late summer and early fall rainfall amounts are substantial. Over Baltic waters east of Sweden and in the Gulfs of Finland and Bothnia, precipitation frequencies range from 9 to 11 percent in August. This is highest for the summer season although it is matched in June in the Gulf of Finland. Clear skies in these waters occur from 35 to 50 percent of the time in summer. Cloudy skies are observed about 30 to 40 percent in the southern Baltic and fall to as low as 25 percent elsewhere. In general, skies are least cloudy in June. There is little variation in summer temperatures throughout the Baltic region, except for cooler temperatures in the Gulf of Bothnia. In June temperatures range (90 percent of all observations) between the mid to upper 40's (degrees F) and the mid 60's. In July and August, the range is between 55 degrees and 72 degrees F. Temperatures in the Gulf of Bothnia are about 5 degrees cooler.

AUTUMN - During Autumn, storm activity increases toward winter levels. The most significant increases are in intensity and size of the lows. The majority of fall storms move between Iceland and the British Isles, and across Scandinavia. In September and October, there is an increase in the number of storms that move across and to the south of southern England. There is also more of a chance for the development of the Skagerrak Low during the fall. In addition, some storms reach the Baltic area from both northern and southern North Sea routes.

Occasionally a high pressure system moves over the area from Greenland. In late fall highs begin to build up over the Soviet Union and Scandinavia and once again are responsible for prolonged spells of quiet cool weather.

September winds over the North Sea are an extension of summer winds with a little more variability. By November the winter regime has become established.

Around the Moray Firth, southeast and south winds are frequent in September as are northwesterlies. By October, here, and September, over the Firth of Forth, a south through west flow is most common. Northerlies and northwesterlies are important secondary winds. Gale frequencies increase from 2 to 3 percent in September 7 to 11 percent by November. Around the Moray Firth, west winds are strongest in September and October, averaging 16 to 17 knots. By November, northwest winds blow at an average 20 knots. Around the Firth of forth, northwest and north winds average 17 to 19 knots and are strongest until November when southeasterlies blow at a 22-knot average. Over the rest of the North Sea southwest through northwest winds become prominent in the fall months. Southerlies and southeasterlies also blow frequently in these waters. Near the entrance to the Skagerrak, easterly winds are common. Wind strength increases toward winter and southwest through northwest winds that average 14 to 18 knots in September average 20 knots or more by November. Near the Skagerrak, when an east wind blows, it averages 20 knots in October and November. Gales occur more often as fall turns toward winter. In September these waters could be sailed with less than a 5 percent chance of encountering gales. By October and November gales are occurring up to 12 percent of the time. They are most likely to be encountered in southeast waters.

Channel winds in fall are variable, but most commonly from the southwest and west. East through south winds are also quite common, particularly in September and October. In the western Channel northeasterlies are important in September. In the central Channel northerlies are frequent in November. Around the Strait of Dover southerlies are still quite common in November and northerlies are a September wind. It isn't until November that the northwest wind establishes itself as the third most frequent Channel wind. Strongest winds blow out of the southwest and west at an average 13-14 knots in September. By November these winds blow at an average 20 knots, along with northwesterlies in the western Channel. Gales are most frequent from the southwest through northwest. They are encountered less than 2 percent of the time in September and from 7 percent in the east to 10 percent of the time in the west by November.

In the Skagerrak, Kattegat and The Sound, September winds are an extension of summer, November winds are a preview of winter and October winds are mixed. In September, winds are most frequent from the southwest through northwest. Easterlies are also common as are southeasterlies. By October southerly through westerly winds are frequent with southeasterlies becoming increasingly persistent and easterlies still a factor.

November brings a little more sense to this distribution when south through west winds become more entrenched followed by southeast except in the Skagerrak where easterlies are a little more frequent. Gales occur just 2 to 4 percent of the time in September and by November are up to 6 to 8 percent; gales are most likely in the Skagerrak. West winds are the strongest and by November they average 22 knots in the Skagerrak and 18 to 19 knots elsewhere.

September in the Baltic Sea also brings an extension of summer winds. Winds from the southwest through northwest are most common during this month. In the south, northeasterly through southeasterly winds form an important secondary flow while around Gotland northerlies are common. During October, there is an increase in the frequency of south and southeast winds in addition to the southwest through northwest flow. By November, south through northwest winds are most frequent with the addition of southeasterlies around Gotland. Southwest is usually the most common direction. Gale frequencies which were less than 3 percent in September, except north of the Gulf of Danzig, are at or near peak occurrence in late autumn. They can be expected 7 to 10 percent of the time during November. In the south, westerlies are strongest averaging 21 knots by September. East of Sweden, southwesterlies average 20 knots in November to take over from northerlies, which averaged 15-26 knots in early fall.

South through west winds are most apt to be encountered in the Gulf of Finland. In September, northerlies are also important. Northwesterlies and southeasterlies become more frequent in October and November. Gale frequencies increase from 3 to 8 percent from September to November. Median wind speeds increase from 9 knots in September to 17 knots by November. In the Gulf of Bothnia, winds are most likely from the south and southwest in September and October and from the south and southeast in November. If they do not blow from these directions, then chances are they will be coming from the north or northwest. Gales become more common as winter approaches; by November they can be expected at least 5 percent of the time. Southeast winds are strongest in November blowing at an average of 18 knots, compared to southwesterlies in October and northerlies in November, which blow at about 15 knots.

Like spring, this is a season of change. The most significant difference between these transitional seasons lies in the lack of fog over open seas in fall. Over large water bodies, like the North Sea, visibilities improve steadily, during the fall, in open waters. This improvement can be traced to the air-sea temperature difference, which is critical to the formation of sea fog; sea fog forms when warm air blows over cool waters. In September, North Sea waters during periods of warm weather are, on the average, 1 degrees to 2 degrees F cooler than the air. This enhances the chances of sea fog formation. By November, sea temperatures during warm spells are, on the average, slightly warmer than the air temperatures, discouraging sea fogs. Near the coasts and in more sheltered waters, the formation of land fog offsets the lack of sea fog, particularly in late fall and winter.

Over northern and central North Sea waters, visibilities below 2 miles occur 8-10 percent of the time in September. By November, these frequencies drop to 4-6 percent. In the southern waters of the North Sea, visibilities below 2 miles become more frequent in October and November as land fog begins to play an important role, particularly near the Dover Strait. This is true despite the increasingly cloudy skies. Clear skies are a prerequisite for land fog formation. They occur more frequently on the coast than they do at sea, particularly at night. In extreme southern waters clear skies (cloud cover less than or equal to 2/8) reach an annual peak of 32 percent in September while cloudy skies (cloud cover greater than or equal to 6/8) occur about 29 percent of the time. By November skies are cloudy about one-half of the time and clear about 16 percent of the time. In the southeast, clear skies are seen only 10 percent of the time by November, down from 20 percent in September. At the same time, the frequency of cloudy skies increases to 60 percent from 40 percent. In central and northern waters clear skies are rare during the fall. In the northwest, skies are cloudiest in September while around the entrance to the Skagerrak, they become increasingly more cloudy as winter approaches. All over the North Sea, precipitation, particularly drizzle and light rain, becomes more frequent during the fall. In northern and central waters early fall frequencies of 14 to 16 percent increase to 16 to 22 percent by late in the season. In the south, frequencies are up to 17 percent from 8 to 10 percent in early season. Snow remains rare over the North Sea

until December. If it occurs it is most likely over central and eastern waters, where temperatures are coldest, on the average. In September, the north-south temperature spread is still evident. Temperatures in northern and central waters range (90 percent of all observations) from 50 degrees to 60 degrees F while in southern seas this range is 53 degrees to 66 degrees F. This gradient remains through October, but by November a slight east-west spread becomes apparent, particularly in the lower part of the temperature range. In the waters near the entrance to the Skagerrak 5 percent of the time temperatures fall below 38 degrees F. Elsewhere this figure is 40 degrees or 41 degrees F. In these same waters temperatures get above 51 degrees F about 5 percent of the time. Elsewhere this figure ranges from 52 degrees F in the northwest to 56 degrees F in the extreme south.

As far as fog is concerned the best time to sail the English Channel would be between the land fog and sea fog season. While no clear cut season of this type exists, October is the closest thing to it. During this month, visibilities in the Channel drop below 2 miles 6 to 10 percent of the time. Visibilities are best in the west and poorest in the central waters. In November poor visibilities are at their annual minimum in the western and central Channel, but land fog has increased the occurrence of poor visibilities in the Strait of Dover region. The biggest change of all takes place in the appearance of Channel skies. In September, clear skies can be enjoyed more than one-third of the time while cloudy conditions dull the skies around one-quarter of the time; a little more often in the west. Skies become duller during October. By November, cloudy conditions are seen 40 to 45 percent of the time. Clear skies are observed 20 percent of the time in the east and just 14 percent of the time in the west. These increasingly cloudy skies reflect the increase in precipitation frequency, particularly light rain and drizzle. In September, rain can be expected about 10 percent of the time. This increases to 16 to 18 percent by November; these are at or near the peak frequencies for the year. The change in temperatures is not so dramatic. There is an average drop of about 10 degrees F from September to November. September temperatures range (90 percent of all observations) from about 54 degrees to 67 degrees F. This holds over the entire Channel. In November temperatures are milder toward the western Channel, on the average. Around the Strait of Dover the range is from 41 degrees to 57 degrees F while to the west this range is 46 degrees to 58 degrees F.

In the Skagerrak and Kattegat, October seems to be the poorest fall month. The frequencies of precipitation and poor visibilities reach an autumn peak at this time. Visibilities which were excellent, particularly in the Kattegat, in September deteriorate in October, when they are less than 2 miles about 10 percent of the time. In November they are less than 2 miles about 6 to 8 percent of the time. In the Sound and entrance to the Baltic visibilities less than 2 miles become more frequent each month and by November can be expected 9 percent of the time. Drizzle and light rain, which helps reduce visibilities, also exhibits the same trend in fall in the Kattegat and Skagerrak. During September and November, precipitation is observed about 10 percent of the time. In October this frequency is about 13 to 15 percent. The opposite occurs to the south where rain can be expected 16 percent of the time in September, about one-half of this percentage in October and back up to 12 percent in November. Skies over these waters become increasingly cloudier as the season wears on. Clear skies which could be viewed one-third of the time in September are seen around 25 percent of the time over the Kattegat in November and near 15 percent of the time elsewhere. In the Kattegat, cloudy conditions occur only 22 percent of the time in September but by November, this figure is up to 42 percent and climbing. Elsewhere, September skies are cloudy about one-third of the time while cloudy skies blanket the area more than one-half the time in November. These cloudy skies along with shorter days cause temperatures to fall, although cloud cover helps keep autumn temperatures above freezing for the most part. September temperatures range from 51 degrees to 64 degrees F. By November the range is from 34 degrees to 50 degrees F. There is little average variation from the Skagerrak to the Sound.

In the Baltic Sea including the Gulfs of Bothnia and Finland visibility is usually good in Autumn. It does deteriorate somewhat in November. Visibilities less than 2 miles can be expected from 2 to 6 percent of the time; 4 to 6 percent of the time in November. Poor visibilities are most frequent in the western Baltic. Snow can reduce visibilities in the northern waters. Snow is first observed with any regularity in the upper reaches of the Gulf of Bothnia in October. By November it occurs up to 5 percent of the time or more over both Gulfs. Over southern waters precipitation in general is most frequent in October and November when it occurs 8 to 10 percent of the time. East of Sweden, it occurs 10 to 13 percent of the time. This rain and snow falls under an increasingly thickening blanket of clouds. Clear skies which were enjoyed up to 40 percent of the time in late summer and early fall, occur only 10 to 20 percent of the time by November. They are least likely north of the Gulf of Danzig and most likely over the waters around Gotland. September skies are cloudy 30 to 40 percent of the time, while bleak December days are cloudy 50 to 60 percent of the time. Temperatures fall 15 degrees F on the average during autumn. September temperatures range (90 percent of all observations) between 50 degrees and 65 degrees F over the Baltic Sea and between 45 degrees and 62 degrees F over the Gulfs. In October, temperatures are mostly in the 40's and 50's November temperatures range between 34 degrees and 50 degrees F in the Baltic Sea. In the Gulf of Finland temperatures range between 27 degrees and 47 degrees F while this range in the Gulf of Bothnia is between 31 degrees and 46 degrees F.

SPECIAL WEATHER-RELATED PHENOMENA

SUPERSTRUCTURE ICING

In certain weather conditions ice accumulating on hulls and superstructures can be a serious danger to ships. Ice accumulation may occur from three causes:

(a) fog with freezing conditions.
(b) Freezing rain or drizzle.
(c) Sea spray or seawater breaking over the ship when the air temperature is below the freezing point of seawater (about 28.6 degrees F).

Ice accumulation from the first two causes, if appreciable, could induce enough damage to the rigging to cause it to fall. This is minor however, in comparison with the weight of the ice accumulated in rough weather and low temperatures, when large amounts of spray and often heavy seas break over a vessel. When the air temperature is below the freezing point of sea water and the ship is in heavy seas, considerable amounts of water will freeze to the superstructure and those parts of the hull which are sufficiently above the waterline to escape being frequently washed by the sea. The amounts frozen to surfaces exposed to the air will rapidly increase with falling air and sea temperatures, and might in extreme cases lead to capsizing of the vessel. The dangerous conditions are those in which gale-force winds last for several days in association with air temperatures of 28 degrees F or lower. These conditions will normally occur when the wind comes from the northern quadrants. Indications of when these conditions are likely to occur can often be obtained by observing the rate of fall of the barometer, at the onset of strengthening winds from a cold quarter, together with observations of air and sea temperatures.

In evaluating the potential for superstructure icing, two categories were subjectively selected. Moderate ice accumulation seems to occur when air temperatures are less than -2 degrees C (28.4 degrees F) and winds are greater than or equal to 13 knots. If air temperatures drop below -9 degrees C (15.8 degrees F) and winds reach 30 knots or more, ice accumulation takes place at an accelerated rate. This category is termed severe. On a small fishing vessel of 300 to 500 tons displacement ice accumulation in the severe category would exceed about 4 tons per hour.

Superstructure icing at its worst can sink a small vessel. It elevates the center of gravity, decreasing the metacentric height. Icing increases the sail area and the heeling moment due to wind action. Its non-uniform distribution changes the trim; it can hamper steerability and lower ship speed. Icing can also cause hazardous deck conditions. Sailing these North Sea-Baltic Sea waters in winter, it is important to be familiar with the location of sheltered coastal areas and warmer currents. It is not advisable to seek shelter in the lee of an ice edge since here air and sea temperatures are often coldest and a wind shift could leave a ship dangerously exposed.

Superstructure icing potential is highest in the Gulfs of Bothnia and Finland. Conditions for moderate icing are present from about October through April. December, January and February are the worst months when potential conditions exist more than 10 percent of the time. The hazard is somewhat less in northern and eastern Baltic waters but conditions exist from 8 to 10 percent of the time in January and February. Potential moderate icing is a possibility from November through April from the Skagerrak to the Baltic. It is less of a threat in the western Baltic and Skagerrak than in the Kattegat and Sound. Superstructure icing is not so common in the North Sea. Potential is highest around the entrance to the Skagerrak in February when conditions occur about 2 percent of the time. The icing hazard is rare in western North Sea waters and there is only a slight chance of it in the eastern Channel and southern North Sea in January and February. The potential superstructure icing statistics can also be found in the summary for selected ocean areas.

OPTICAL PHENOMENA

A wide variety of optical phenomena such as mirages, green flashes, solar arcs, halos, coronas, ice blink, land blink, aurora borealis, and St. Elmo's fire are observed in these waters.

A mirage is caused by refraction of light rays in a layer of air having rapidly increasing or decreasing density near the surface. A marked decrease in the density of the air with increasing altitude is the cause of such phenomena known as looming, towering, and superior mirages. Looming is said to occur when objects appear to rise above their true elevation. Objects below the horizon may actually be brought into view. Towering has the effect of elongating visible objects in the vertical direction. A superior mirage is so named because of the appearance of an image above the actual object. Ships have been seen with an inverted image above and an upright image floating above that. Such mirages, especially with looming and towering, are fairly common in the area with frequency increasing toward the higher latitudes. They are most common in summer when the necessary temperature conditions are most likely. Another type, the inferior mirage, occurs principally over heated land surfaces such as deserts but may be observed occasionally in

shallow coastal waters, where objects are sometimes distorted beyond recognition. In contrast to the superior mirage, the condition necessary for the inferior mirage is an increasing air density with height. Atmospheric zones of varying densities and thicknesses may combine the effects of the various types of mirages to form a complicated mirage system known as Fata Morgana.

The green flash is caused by refractive separation of the sun's rays into its spectral components. This may occur at sunrise or sunset when only a small rim of the sun is visible. When refractive conditions are suitable, red, orange, and yellow waves of sunlight are not refracted sufficiently to reach the eye whereas green waves are. The visual result is a green flash in the surrounding sky.

The refraction of light by ice crystals may result in many varieties of halos and arcs. Because red light is refracted the least, the inner ring of the halo is always red with the other colors of the spectrum following outward. Halos with radii of 22 degrees and 46 degrees have been observed with the refraction angle within the ice spicules determining which type may occur.

Solar and lunar coronas consist of a series of rainbow-colored rings around the sun or moon. Such coronas resemble halos but differ in having a reverse sequence of the spectrum colors, red being the color of the outer ring, and in having smaller and variable radii. This reversed sequence of the spectrum occurs because coronas result from diffraction of light whereas the halo is a refraction phenomenon. The radius varies inversely as the size of the water droplets. Another type of diffraction phenomenon is the Brocken bow (also known as glory) which consists of colored rings around shadows projected against fog or cloud droplets.

Ice blink, land blink, and water and land skies are reflection phenomena observed on the underside of cloud surfaces. Ice blink is a white or yellowish-white glare on the clouds above accumulations of ice. Because of the absence of ice in the open seas, ice blink is likely only from late autumn to early spring in parts of the Baltic Sea, especially the Gulfs of Bothnia and Finland. Land blink is a yellowish glare observed on the underside of clouds over snow-covered land. Over open water and bared land, the underside of the cloud cover when observed to be relatively dark is known as water sky and land sky. The pattern formed by these reflections on the lower side of the cloud surfaces is known as a "sky map."

St. Elmo's fire may be observed occasionally, during stormy weather. The "fire" appears as a bluish luminous brush discharge of electricity and is most likely to be seen leaping from ships' masts and spars. St. Elmo's fire is also known as Corposan, from corpo santo, or ghost because of its once supposed supernatural nature.

Aurora borealis is observed frequently in the northernmost parts of the area, just south of the maximum zone of occurrence of this phenomenon. It can be observed about 20 percent of the time in northern Scotland and 5 percent in northern England. The frequency of aurora borealis on clear dark nights over the Baltic Sea is less than 5 percent, and over the Gulf of Bothnia the frequency varies from 10 percent in the south to 30 percent in the north. The probability of occurrence is greater during periods of maximum sunspot activity. As a result of the position of the earth at the equinoxes, there is a spring and autumn maximum in auroral activity. Daily reports indicate a diurnal maximum at about 2300.

ENGLISH CHANNEL

EXTRATROPICAL CYCLONES

Lows can cause problems in the English Channel year round. By far, the most common situation in any season is a low pressure system north of the British Isles and a high to the south. This is particularly dangerous in winter when these storms are often intense.

The storms that pass far to the north bring bad weather but changes are gradual. They often trail weather-producing fronts across the Channel. Cold fronts often bring this sequence of events: 1) increasing cloudiness and wind speed, 2) rain and possibly southwesterly gales, and 3) clearing and strong northwesterly winds. These systems can occur in families, which restrict the clearing period. Open low pressure systems, called waves, can form on these fronts and bring additional trouble. Parent lows and intense waves that pass close to, but north of the Channel bring bad weather and rapid changes. Winds are variable and shift suddenly. Gales are likely and squalls often accompany fronts.

Storms are most intense in winter, but more pass over the British Isles in spring. In the fall storms often move south of the Channel. This occurrence causes no sudden changes. Winds back gradually from east through north. This brings a cold flow of air, sometimes from the Greenland-Spitzbergen region. In late fall and winter there is a possibility of snow and gales.

Storms are weakest and farthest north in the summer. Most move well north of the British Isles. The two most common summer situations are a low near Iceland or a low in the Norwegian Sea with highs south of the Channel. Occasionally a weak low or a large high will center itself over the British Isles.

Forward speeds of lows are variable, and range up to 40 knots. Most common are speeds from 5 to 10 knots. Sometimes a low will become stationary near Iceland. This brings several days or more of southwesterly winds.

WINDS-ENGLISH CHANNEL

Winds within 20 miles of the coast are often subject to topographic effects. If a coast is bordered by steep cliffs or there are high hills or mountains paralleling the coast, a short distance inland, then onshore winds inclined to the coast are usually deflected and blow nearly parallel to the coast at an increased speed. This is particularly noticeable in a long narrow strait. When onshore winds blow nearly perpendicular to a high coast, there is often a narrow belt of contrary gusty winds close to the coast. An offshore wind is often squally on the lee side of a hilly coast especially where the air is much cooler than the sea surface. Land and sea breezes develop near the coast particularly in spring and summer during fine settled weather. Along the English coast from December through February, winds blow from the southwest through northwest about one-half of the time. The French coast experiences a fair percentage of southerly winds, and in some locations they are more prevalent than southwesterlies. In general, the predominant flow is between south and west. Along both coasts northeasterly and easterly winds are also common in winter.

Along the Strait of Dover coasts, southwesterlies are more frequent than anywhere else all year round, and occur 20 to 30 percent of the time in winter. In the approaches to Brest northwesterly winds predominate in nearly all months. Brest itself is sheltered somewhat. Even in winter calms occur 10-12 percent of the time compared to 2 to 7 percent at other ports. Coastal wind speeds are highest in winter. Averages range from 16 to 20 knots at exposed locations like the Scilly Isles and Ile d'Ouessant to 8 to 12 knots at sheltered ports like Brest and Dungeness.

In Spring, winds become even more variable. On both sides of the Channel northerly, northeasterly and easterly winds are often slightly more frequent than southwesterlies and westerlies. At some ports the two most frequent winds are directly opposite; at Dunkerque, northeast and southwest winds prevail while on Scilly Isles west and east are the two most common directions. Winds from the northwest are also frequent. Along the Dover Strait southwesterlies still prevail but northeasterlies are a strong second. Spring brings a decrease in wind speeds. This is reflected in the mean speeds which range from 8 to 17 knots.

With an increase in clear and mild weather from late spring through early fall, the land-sea breeze regime establishes itself. The heating of the land faster than the water during the day sets up an onshore flow. As the land cools quicker at night, an offshore flow is established. When there are no interfering weather systems, this flow prevails with unerring frequency, at other times it superimposes itself on the existing flow to some degree and can reinforce, oppose or deflect this flow. Along both English Channel coasts the daytime sea breeze often reinforces and increases the frequency of southwesterly and westerly winds in summer when it is strongest. At Calais southwesterly winds make up 45 percent of the observations during July and August. In general, near the coast the frequency of southwest and west winds increase during the day, while northeasterlies, northwesterlies and calms increase at night. Coastlines with a northern exposure to the sea tend to experience an increase in northerly onshore winds during the day. At Falmouth morning calms occur 9

percent or more of the time from April through September. By early afternoon calms are observed only 3 to 4 percent of the time. The land- sea breeze effect at Falmouth is reinforced by the configuration of the Penryn River. The result is a high frequency of southwesterlies in the afternoon and northerlies in the morning. Plymouth experiences this same effect. At Portland Bill, the sea breeze effect results in a tendency for northerlies and northeasterlies to veer toward the east and for westerly to northwesterly winds to back toward the southwest. At Dungeness southwesterlies occur 32 percent of the time on July mornings and 54 percent of the time in the afternoon. Around the Isle of Wight, winds often blow along the Solent and Spithead under the sea breeze system. On a quiet warm day the main breeze will blow either from the southwest up the Solent or from the southeast up Spithead. Sometimes a morning southeast wind will veer southwestward during the day. The land breeze blows on clear nights throughout the year, and is often more marked in winter. It flows most often from the northwest down to Southhampton Water. Wind speeds are lightest during the summer and they show a noticeable diurnal variation. Mean speeds increase from 6 to 9 knots during the morning to 12 to 14 knots in the afternoon. Afternoon sea breezes can reach 20 knots.

Autumn brings a return to the more variable, less predictable conditions that existed in spring. Even along the Strait of Dover, where southwest winds prevail, there is a significant increase in winds from the west through north. The highest frequency along the Channel coasts is in winds from the southwest through northeast, but at some locations east winds prevail and at others southeast winds are the most common. At Brest during October and November, calms are the prevailing condition occurring 14 to 17 percent of the time. Autumn wind speeds are on the increase toward the winter maximums. The mean speeds range from 6 to 8 knots at sheltered locations to 15 knots at exposed sites.

GALES-ENGLISH CHANNEL

Coastal gales, like lighter winds, are influenced by exposure. Gale frequencies near the coast may be less than one-half of nearby open water frequencies. Whether a stretch of coast is sheltered depends on wind direction. A coast sheltered from a southerly gale may suddenly be exposed if the gale veers to the west. This occurs in Mounts Bay and Portland Harbor. High ground to windward may not always provide the shelter expected. For example, along the Dartmouth coast a wind blowing from off the high ground often generates turbulent squalls in coastal waters. This is particularly true with a west-northwesterly flow in Dartmouth Harbor.

Along the English coast the average annual number of days with gales ranges from 3 days at Dover to 35 days at Falmouth. Gales are most likely from October through April; December and January are the heart of the season. Falmouth is particularly exposed to strong winds and gales. It has an average of 7 gale days per month in December and January. Scilly Isles and Portland Bill are exposed locations subject to nearly three-quarters of the gales that occur in open waters. Coastal gales are most common from the southwest through northwest. A southwesterly gale will sometimes veer to the northwest or north without losing strength. In April and May the infrequent gales are often from the northeast. Gales vary in duration. Along the western shore they usually last 4 to 5 hours. Along the English coast in the eastern Channel gales usually last about 2 hours.

The French coast is more exposed to gale-force winds than the English coast. Gales are most likely from September through May. Gale days range from 69 at Brest to 13 at Jersey Airport. December through February are the roughest months. Cherbourg is a well-sheltered port, while nearby Cap de la Hague is exposed to gales on about 6 days in December. This compares to an average of 3 gale days in December at Cherbourg, which is exposed to gales from the northeast. At St. Inglevert near Calais, gales occur on an average of 47 days a year and 5 to 7 days per month from October through February. St. Inglevert is particularly exposed to southwesterly gales. The direction of strong winds along the French coast is important to sea state. Between Brest and Cherbourg roughest seas are generated by strong southwesterly through northwesterly winds. From Cherbourg to Dunkerque, roughest seas are associated with strong winds from the northwest through northeast.

VISIBILITY-ENGLISH CHANNEL

Fog is responsible for most of the poor visibilities that occur in the English Channel. Near industrial areas fog is often intensified and prolonged by smoke. Sea fog and land fog affect the Channel and both have favored locations.

Sea fog, which forms when warm, moist air moves over cooler water, occurs most often from late spring through fall. Favorable conditions are found in the warm sector of a low and the fog can occur in fresh winds or even gales. It is most likely with southwesterly to westerly winds. While mainly a summer hazard, sea fog occurs two or three times in winter and can penetrate eastward as far as Dungeness. In general, however, sea fog is most prevalent in summer in western waters. At times, it is possible to find an open area near the coast when midchannel is foggy. Near the coast, summer sea fog is most frequent in morning.

Land radiation fog, which forms when moist air is cooled below its dewpoint by contact with the cold ground, is prevalent from late fall through early spring. Favorable conditions are found in the clear skies and light winds of a large high

pressure system. Inland, radiation fog often dissipates during the day, but near the coast, particularly in midwinter, it can persist for a day or more. It may also drift into the Channel and persist if it remains over cool waters. On 1 or 2 days per winter month, radiation fog will completely enshroud the Strait of Dover. This is a real navigational hazard. Radiation fog is aided by smoke. Plymouth Hoe experiences about 4 to 5 days per winter month of radiation fog enfused with industrial smoke. Less than 1 mile away, across Cattewater, Mount Batten is relatively fog-free during this period.

Radiation fog is local and very liable to form in hollows or over low-lying ground near rivers, particularly near smoke sources. Sea fog is prevalent along the Channel coasts west of Portland Bill and Cherbourg. In spring and summer visibilities drop below 1/2 mile at a peak of 3 to 8 days per month. At Lizard and Cap de la Hague, this peak is in July. At Portland Bill and Falmouth, May is the peak fog month; both types of fog occur during May. Summer sea fogs are most common with southerly to westerly winds. In winter, radiation fogs, and occasionally a sea fog, occur along these coasts on usually less than 3 days per month.

Radiation fog prevails east of Cherbourg and Portland Bill. Poor visibilities occur most often in winter. While radiation fog is local, it often becomes widespread in the Strait of Dover. Winter visibilities along the coasts drop below 1/2 mile about 4 to 6 days per month at a peak. Visibilities of less than 5 miles can occur on up to 15 days per month. At Southampton and Southampton Water, industrial smoke pollution helps keep visibilities below 1/2 mile on 5 to 6 days per winter month. Summer visibilities along these coasts drop below 1/2 mile on less than 2 days per month at most locations. At St. Inglevert and Le Havre they occur on 2 to 4 days per month in summer.

CLIMATE-ENGLISH CHANNEL

Fall and winter are dreary times along the English Channel coasts. Days are cloudy, rainy and mild, while nights are damp and chilly. Cloudy conditions (cloud cover greater than or equal to 8/10) occur on up to 20 days per month while rain, or sometimes snow (1 to 3 days per winter month), can be expected on 15 to 25 days per month. Cloud cover and the relatively warm waters keep temperatures and relative humidities from varying too much from day to night. Relative humidity, dependent on temperature and moisture, varies from 86 to 93 percent during the early morning hours down to 80 to 85 percent in the afternoon. Nighttime temperatures range from 35 degrees to 40 degrees F while daytime highs climb into the mid to upper 40's.

Sometimes skies clear for a short period between frontal systems or longer when a frigid high pressure system moves over the area from the northeast. These clear conditions occur on the average of 4 to 7 days per month. It is during these spells, that nighttime temperatures are most likely to fall to freezing or below. When clear conditions persist for a week or more in conjunction with a frigid high, temperatures can fall to 20 degrees F or below. How cold it gets depends on the land and water influence. The oceanic Scilly Isles rarely experience temperatures below freezing. At a more land-tempered port like Dungeness, minimum temperatures fall to freezing or below on 9 to 11 days per winter month. Extreme temperatures range from 9 degrees F at Dungeness to 20 degrees F at Falmouth and 25 degrees F on the Scilly Isles. When a persistent southwesterly flow blows across the channel in winter, unseasonably warm temperatures can occur. Maximum temperatures in extreme occurrences reach 60 degrees F.

With the coming of spring and then summer, days turn brighter, rain falls less frequently, and temperatures slowly moderate. Even relative humidities drop off slightly. Cloudy skies are seen on the average of 10 to 20 days per month while clear skies are observed on up to 10 days per month. Partly cloudy conditions are most prevalent in the afternoon and are often associated with showers. By June, most coastal towns experience measurable rain on just 8 to 13 days. April, May and June are the driest months of the year. Thunderstorms become more frequent as spring turns to summer. They occur on up to 2 days per month. It is this showery weather that is responsible for the greatest 24-hour rainfalls, which occur in the summer. Extreme 24-hour amounts range from 2 to 4 inches along the Channel coasts. These are scanty totals when compared to the world's 24-hour record of 73.62 inches at Cilaos, La Reunion.

The advancing season in combination with less rain and more blue sky moves spring daytime temperatures into the upper 50's to mid 60's. Nighttime lows average in the upper 40's. During the hottest part of the year-July and August-average maximums range from 65 degrees to 70 degrees F while average minimums reach the mid 50's. Rising temperatures drop relative humidities. However, this is partially offset by sea breezes and other winds from off the Channel. Afternoon relative humidities reach a low during spring or summer of from about 70 to 75 percent. During the night they tend to climb back into the 90 percent range. The Channel waters continue to moderate temperature extremes. The number of days that maximum temperatures reach or exceed 86 degrees F is nil. Extreme record high temperatures are generally somewhere in the 90's. Extremes at more exposed stations are usually in the 80's.

The turn from summer to fall is gradual. September retains many summer characteristics. Daytime temperatures still reach the 60's, clear skies can be seen on as many as 8 days and rain is observed on less than one-half of all September days. During October the progression toward winter becomes more apparent. Rain is measured on about 15 to 20 days, days become noticeably cooler and clear skies are uncommon.

NORTH SEA

EXTRATROPICAL CYCLONES

The most intense storms affect the North Sea in fall and winter. The main path of storms lies between Scotland and Iceland. Storms also move across the British Isles and then northeastward to Norway. Occasionally a storm will move across southern England or through the English Channel and into the Baltic Sea. About 60 percent of all North Sea winter storms develop gale-force winds. Many are intense secondary lows that form south of a major system. These can move across the North Sea at speeds up to 40 knots. Gales most often accompany southwesterly through northwesterly winds. Fronts associated with these storms are most active in winter. A well-developed storm between Iceland and Scotland, with its frontal systems, can cover 1,000 miles.

Most winter storms move well to the north of the southeast coast of the North Sea. They bring southerly to southeasterly winds, rising temperatures, cloudiness and occasional showers to these shores. As the low passes, winds shift to the southwest and west with cooler weather and showers. When lows pass close to these shores or a vigorous cold front moves in from the north, the accompanying high seas are a menace to the low-lying farmlands and villages. Northerly winds have the longest fetch.

As spring progresses, the primary storm track shifts southward into the North Sea. There is, however, a considerable decrease in intensities even though summer brings the greatest number of lows. Less than 10 percent of these storms generate gales. Frontal activity is at a minimum in summer. Frontal zones are usually narrow with showers and rapid clearing after the front passes.

WINDS-NORTH SEA

A year-round procession of lows and fronts through or near the North Sea produces varying, frequently shifting winds. When days are long and storms are weak, the seasonal land-sea breeze provides a steadying effect. Topography influences winds on all coasts in all seasons, but is most noticeable in the gusty squalls that come blowing off the Scottish highlands and roaring down the Norwegian Fjords.

Since so many winter storms remain north of the area, a general southwesterly to westerly flow prevails. This flow is deflected to the southeast around Norway. Spring and autumn combine the closer-passing but weaker storms with a land-sea breeze effect to produce a varied and complex wind regime. Summer winds are the product of normally weak pressure gradients and the influential land-sea breeze pattern.

England and Scotland.- Winter winds at Wick, Scotland blow from the south through northwest about 90 percent of the time. These are part of the strong, shifting winds that blow off the east coasts of Scotland and England. Direction and speed are influenced by exposure. At Inverness, wind directions are more confined to south and southwest while westerlies are most frequent at Tynemouth and Spurn Head. Greenwich favors a relatively prevailing southwesterly flow. Exposed locations like Wick are subjected to winds that blow at an average of 15 knots while protected ports like Inverness register 6-knot averages in winter. Spring winds are weaker but more complex than the winter flow. More, but weaker, storms pass directly over the area and the land-sea breeze begins to take hold. Winds in general and afternoon winds in particular begin to come more and more off the water during March. While southerly through westerly winds still prevail, they are less frequent than in winter. Winds from the north through southeast are slowly becoming an accepted afternoon feature. The weaker storms drop wind speed averages to 5 to 12 knots. A slight afternoon increase is apparent. This windspeed increase reaches an average of 3 to 4 knots in summer. Summer winds are a blend of the variable flow around weak, infrequent storms and the steady reversible flow of the land and sea breezes. Sometimes these forces combine to produce a strong flow and other times they are at odds and the flow is weak. On clear, mild days, light westerly to southwesterly morning winds gradually reverse to become northerly through southeasterly at average speeds of 12 knots during the afternoon. When these ideal conditions are not present, the sea breeze may still alter existing flow. For example, at Wick the sea breeze helps make southerly winds an important afternoon feature by rerouting existing southwesterly and westerly flow. When cloud cover prevents sufficient heating of the land or when the pressure gradient is strong, southwesterly to westerly winds can prevail all day. Summer mornings are often beset by calms, particularly at sheltered locations. An excellent example is Inverness where morning calms occur 13 to 22 percent of the time, year-round, including 19 to 20 percent on fall mornings. However, in general, autumn brings an increase in wind speeds and more variable directions as storms become more intense and days grow shorter. Average winds along exposed shores are up to 15 knots again by October. The increase in frequency of southerly through northwesterly winds signals the approach of winter.

Belgium, Netherlands, and Federal Republic of Germany (West Germany)- The winter wind season is shorter along the coasts of Belgium, the Netherlands and West Germany. The relatively predictable flow of south through west winds lasts

only through January. Late winter storms and increasing daylight are responsible for a noticeable variability in winds by February. Northwest winds infrequent until now, become more prominent since storms are passing closer to these shores. Southerly to southwesterly winds are the most common in December and January. During February, northwesterly through easterly winds are on the increase. Average wind speeds also begin to fall from a midwinter peak of 20 knots along exposed shores and 8 knots at the more protected ports. Zeebrugge, Belgium is an exception that averages 13 to 15 knots year-round. By March a northeasterly through easterly flow may be as frequent as winds from the southwest and west with winds off the water more frequent during the afternoon. At Hoek Van Holland in April the frequency of northerly winds increases from a morning value of 15 percent to 26 percent in the afternoon. Here and along most of the coast, the sea breeze merely alters the existing flow. The pure sea breeze is more likely to come from the west at Hoek van Holland and from the west through north along other coasts. At Vlissingen in July west winds are observed 16 percent of the time in the morning and 41 percent of the time during the afternoon. At Bremerhaven, the frequency of the July northwest wind increases by 26 percent from morning to afternoon. The land-sea breeze effect also produces an average 2 to 3 knot increase in average wind speeds. Afternoon speeds average 15 knots along exposed coasts and about 10 knots at more protected locations, such as Hamburg. General summer wind flow ranges from southerly to northwesterly with offshore components more likely during the night and early morning hours and onshore components most frequent during the afternoon. The land breeze is weaker and less influential than the sea breeze. Although the land-sea breeze effect extends into Autumn, it is made secondary by the major storm systems which once again plague the North Sea. The extremely variable fall winds, including a heretofore uncommon southeasterly flow, gradually revert to the south through west winter pattern. Wind speeds increase with averages of up to 16 knots along unprotected coasts.

Denmark and Norway.- Along the North Sea coasts of Denmark and Norway, storms and topography tend to back the general southwest winter flow toward the east. Winter winds tend to blow out of the northeast through southwest in Denmark and out of the east through south along Norway's shores. The easterly component in Norway is aided by the outflow of cold air from the high interior. Average wind speeds range up to 15 knots along Norway's coasts but most ports are protected and average speeds at these places range from 6-10 knots. In an extreme case of sheltering, Sauda, a small industrial town, has an average wind speed of 2-3 knots year-round. Average winter wind speeds along the Danish coast range from 8 to 12 knots. As winter turns to spring, winds become more variable with an increase in the frequency of southwest through northwest winds. By late May the sea breeze helps boost the frequency of afternoon winds from off the water. Wind speeds start to increase during the day. Afternoon speeds average between 8 and 12 knots. This afternoon increase reaches a peak in summer when morning winds are lightest. Summer winds blow mostly from the south through southwest along the Danish coast and from the west through north along Norwegian shores. The sea breeze influence is now at its peak. Southwesterly winds, prevalent on summer mornings in Denmark, become even more persistent during the day while prevailing northwesterly and northerly winds in Norway are increased by about 12 percent during the day. Summer afternoons at Lista give rise to northwesterlies 38 to 44 percent of the time. The land breeze is infrequent along these shores since it opposes most normal flow. It appears only on calm clear nights and blows from an easterly direction. It becomes even less frequent with the coming of fall. During this transitional season, there are quiet times when the sea breeze brings a brief return to summer. Then suddenly a large storm sweeps in off the Atlantic and the strong, shifting winds of winter prevail. Average wind speeds are on the increase. As fall wears on, winds with easterly components become more and more frequent, heralding a return to winter.

GALES-NORTH SEA

Winter storms, with their fronts, are responsible for most of the strong winds and gales along the North Sea coasts. On the prominent shores of Scotland and Norway, topography lends a helping hand. The prevailing winter flow in Scotland comes off high ground and often develops into squalls that blow down slopes and valleys. This can cause gusty winds above gale force along the coast. In Norway tablelands drop abruptly into the sea and are separated by deep fissures known as fjords. Cold air, which builds up over the highlands in winter, pours down the steep slopes creating gusts along the coast. This is often triggered by an approaching low pressure system. During these spells, even more violent winds occur in the fjords where cold air outflow is channeled and its speed greatly increased. Squalls build to maximum strength within an hour or two. They are particularly treacherous since they occur in cold, clear weather with little warning. These gales that menace fjord navigation are known locally as Elvegusts. Terrain also provides shelter from gales. For example, Aberdeen, on the section of the Scottish coast protected by mountains to the west and northwest, experiences fewer days with gales in a year than does nearby Wick in a typical January.

Along the east coasts of Scotland and England, gales are most likely from September through May. Strong winds and gales can occur in a line squall preceding or accompanying a cold front. This event is heralded by a line of low black clouds to the west or northwest. These line squalls may occur in any season and are experienced once or twice a season along any section of coast. Local gale frequency is largely determined by exposure to southwest through northwest winds. At unprotected ports like Wick and Edinburg, gales can be expected on just under 25 days annually. Most ports are more sheltered and experience 2 to 12 gale days in an average year. The infrequent gales of summer are associated with violent afternoon thunderstorms and may come from any direction. Extreme winds are most likely in

winter. Record gusts of 88 knots have occured at Dyce in January and at Bell Rock in November. Edinburg recorded a 75-knot gust in January.

The Netherlands and Belgium coasts are most often exposed to gales from the southwest through north. The Netherlands is usually more susceptible to strong winds. Gales occur on 10-20 days during an average year and on up to 3 days per month from October through March. Inland ports such as Amsterdam and Rotterdam are more sheltered. At Amsterdam winds greater than or equal to 28 knots occur on about 17 days annually while gale-force winds are observed on just 1 or 2 days each year. Although strong winds are most frequent and most severe in winter, occasionally a violent summer thunderstorm can cause local winds of 50 knots or more along these coasts. On rare occasions, small tornadoes or waterspouts have been sighted with thunderstorm activity. Extreme winds are most likely in winter and register around 60 knots along exposed shores. At Den Helder, sustained winds have reached 56 knots and gusts have reached 78 knots. Zeebrugge has recorded a 54-knot extreme in November and a 50-knot wind in May. At Terschillingerbank, 60-knot winds have been observed in December and March.

Even more exposed than the Low Countries is the coast of West Germany where strongest winds blow from the south through west. The rock island of Helgoland, at the mercy of the sea, is besieged by gales on an average of 63 days annually, and a peak of 10 days per month in November and January. Closer to the coast wind speeds diminish. Borkum, in the East Frisian Islands, experiences winds equal to or greater than 28 knots on 3-6 days per month from September through February and 1-3 days per month during the rest of the year. At Bremerhaven winds of 28 knots or more occur on 2-3 days per month from October through April. Hamburg's winds seldom get above 28 knots. Gales are infrequent along Denmark's western shores. They occur on about 5 to 10 days a year and on about 1 day per month from September through April. The open coastal waters of southwest Norway are subject to frequent gales. At port gales are less common. In mid-winter gales occur on up to 12 days per month in coastal seas and on 4 to 6 days per month in summer. Sheltered ports like Lindesnes and Bergen average 1 to 3 gale days per month from September through April. Less protected places such as Lista and Stavanger average 4 to 5 gales days per month during this period. Summer gales are rare.

CLIMATE-NORTH SEA

Winters along the North Sea coasts are usually mild, drizzly, foggy and damp. Frequent North Atlantic low pressure systems and infrequent Siberian Highs make up the winter climate. The weather at individual ports or along specific coasts depends largely on exposure to prevailing winds, closeness to storm centers and the industrial makeup of the area. The short winter day also contributes to the North Sea climate.

The numerous storms that frequent the North Sea and nearby waters bring a varied, abundant cloud cover that blocks 80 to 90 percent of the sunshine available on these short days. Cloudy conditions (cloud cover greater than or equal to 6/8) occur on about 18 to 25 days per month except along the normally leeward eastern shores of Great Britain where they are seen on about 12 to 16 days per month. This cloud cover helps keep temperatures down during the day and up at night. The diurnal range averages 6 degrees to 10 degrees F in winter. The cloud cover indicates moisture and this is reflected in relative humidities that average in the mid to upper 80 percent range. Yet with all the moisture, the storms and the cloudiness, precipitation amounts are, for the most part, light.

The east coasts of Scotland and England benefit from that leeward protection while the southeastern coasts from Belgium to Denmark are usually too far south of the storm centers and heavy rain areas. Precipitation amounts range from 2 to 3 inches per winter month. The southwest coast of Norway benefits from neither of these effects and here precipitation amounts range from 4 to 9 inches per month. The scanty amounts along the other coasts accumulate over a large number of days. Measurable precipitation (greater than or equal to .004 in.) is observed on about 14 to 20 days per month. Norway's precipitation falls on about 18 to 24 days per month and much of this falls as snow. Other areas receive little snow. This is reflected by the temperatures. Average winter daytime maximums range from the mid 30's (degrees F) along West German and Danish shores to the mid 40's along the southeast coast of England. Nighttime lows range from around freezing in Denmark, Norway, West Germany and the Low Countries to the mid 30's in England. These are not ideal conditions for frequent snows, particularly since below normal temperatures often occur with clear skies. Minimum temperatures drop below freezing from October through May. In mid-winter this occurs on 18 to 20 nights per month in Denmark and Norway, 10 to 17 nights in the lowland countries and 6-12 nights in Great Britain. These are average general conditions to which there may be exceptions. For example, at exposed Spurn Head below freezing temperatures occur on a maximum of just 3 to 4 days per month. At Nairn, near Inverness in the Moray Firth, temperatures drop to freezing or below on 12 to 19 days per winter month, with most occurrences in March. However, snow does fall on an average of 10 to 20 days annually along the shores of England, the Netherlands, Belgium and West Germany. This average jumps to 20-35 days in Scotland and Denmark and to 35 to 50 days along the southwestern coast of Norway. The snow season runs from November through April except in Scotland and Norway where it normally extends from October through May.

There are some periods on these North Sea coasts when it isn't raining or snowing. The number of days when clear skies are observed, averages between 2 and 8 days per winter month. These periods are most likely between fronts or with the oubreak of a continental high pressure system. These highs are responsible for the coldest winter days. Record low temperatures can be neared or broken during these spells. Extreme low temperatures depend upon exposure and range from around 16 degrees to 9 degrees F along the Great Britain coast, from 16 degrees F down to -2 degrees F along the Belgium-Netherlands coast, down to -7 degrees F at some interior ports in West Germany. The Jutland coast of Denmark has recorded extremes to about 0 degrees F and along the southwestern coast of Norway temperature extremes range from 10 degrees F down to -8 degrees F. Drastic temperature drops of 20 degrees to 30 degrees F can occur in Norway when cold air rushes down fjords. It is during these clear cold periods that most ports are highly susceptible to fog.

Fog is often aided by industrial smoke, which by itself can sometimes lower visibilities to less than 1 mile. Winds can spread this smoke over great distances. Winter fog is local, however, and needs sheltered conditions in order to thrive. For example, along the Netherlands coast visibilities drop to or below 5/8 mile on up to 11 days per month, while nearby lightships experience these conditions on just 4 to 6 days. At sheltered Inchkeith, Scotland, in the Firth of Forth, the fog signal is heard an average of 108 hours in February. A short distance away at exposed St. Abb's Head, their fog signal sounds an average of 21 hours in February. Fog depends on moisture, and relative humidities are high all year 'round on North Sea coasts. The average diurnal range of humidities is small in winter, averaging just 2 to 6 percent. Along most coasts, relative humidities range from the upper 80's to mid 90's (percent) in the early morning and from the low to upper 80's in the afternoon. Along the Norwegian coast, this range is from the low 80's to the mid to upper 70's.

Spring is a pleasant season of transition along the North Sea coasts. As the days grow longer, temperatures rise, cloudiness and rain are less frequent and humidities are lower, although fog is still present. While lows are more likely to move directly over the North Sea, they are much weaker than the severe winter storms. Their southward shift along with an increase in northeasterlies bring more cloudiness to the former leeward coasts of Great Britain. Cloudy skies (greater than or equal to 6/8) are now observed on up to 20 days per month along the east coasts of England and Scotland. Elsewhere, however, cloudiness is decreasing; by May cloudy conditions are observed on 8 to 16 days. Along with an increase in radiation, this causes temperatures to rise and also causes a greater difference between maximums and minimums. During spring average maximums rise from the 40's (degrees F) to the upper 50's and low 60's. Minimums jump from near freezing to the low to mid 40's. These temperature increases result in a drop in relative humidities and an increase in the diurnal spread. By May morning maximums are in the 75 to 90 percent range while afternoon minimums range from the mid 60's to the mid 70's. The relative humidities indicate that May and June are the two driest months. This is also reflected by precipitation. From February through May average monthly precipitation amounts range from 1 to 3 inches, and up to 6 inches along the southwest Norwegian coast. Those bleak rainy days are also on the decline and measurable precipiation can be expected on 8 to 16 days per month in spring. There is a further decline in rainy days during summer but this is offset by heavier falls in showers. Although humidities are lower and rain is less, fog is still a problem in spring. Spring is a season of two fogs- land (radiation) and sea. Some locations are subject to both under the right conditions. Many of these locations reach a peak in fog frequency during March. During this month visibilities fall to or below 5/8 mile on 4 to 8 days. The clear conditions (sky cover less than or equal to 2/8) needed for land fog formation are observed on 3 to 6 days per month. At sheltered locations spring marks the end of the fog season. By May, fog is becoming more infrequent almost everywhere. Frequencies are falling toward a summer minimum.

Summer is a relatively cool, wet season with occasional periods of hot, dry weather. The length of the day is around 16-18 hours, about twice that of winter. Sea breezes and prevailing winds off the water keep maximum daytime temperatures in the 60 to 70 degrees F range. Temperatures in general decrease northward; coldest temperatures are found along the coasts of Scotland and Norway. Temperatures are also restricted by cloudiness. In the early morning low clouds, haze and smoke are often present and during the afternoon cumulus type clouds develop. Average cloud cover ranges from 5 to 6 octas (eighths). Clear days, less common than they were in spring, range from 2 to 8 per month. Cloudy days are more common and range from 14 to 22. Afternoon clouds are often convective giving rise to showers and thunderstorms. Monthly rain amounts usually increase as the summer wears on. By August amounts of 2 to 4 inches are common, except in Norway where the range is from 4 to 7 inches. Showers can be heavy and maximum 24-hour amounts are usually in the 2 to 3 inch range; Yarmouth Roads measured 4.8 inches during one August shower. Thunderstorms are most likely in the summer and are usually isolated late afternoon occurrences. They are most frequent from southeast England along the Low Countries to West Germany. On these coasts thunderstorms occur on 3 to 6 days per month from late spring through early Autumn. Elsewhere they are infrequent and occur on just 1 to 2 days per month. Thunderstorms and showers briefly reduce visibilities. Summer visibilities are usually good. The northeast coast of Scotland is susceptible to sea fog and at Wick visibilities drop below 5/8 mile on 3 to 4 days per month. Along most coasts a light early morning fog is common; this is mainly radiation or land fog. It is prevalent around industrial areas and can reduce visibilities below 5/8 mile on up to 3 days per month at places like Vlissingen, Emden, Bremen, Hamburg and Stavanger. However, it usually reduces visibilities to just below 2-1/2 miles in the early morning. During the morning hours, the stable conditions that support this fog disappear as the air is heated and becomes more

turbulent. Visibilities quickly improve. The moisture needed to support these fogs is reflected in the relative humidities. If the actual moisture content of the air remained the same year round, then relative humidities would be lowest in summer when temperatures are highest. However, sea breezes and prevailing winds increase moisture and relative humidities are higher than spring and increase throughout the summer. Early morning, maximum relative humidities increase from the mid 70's (percent) and low 80's to the mid to upper 80's by summer's end. Minimum afternoon relative humidities do not increase and remain in the 60 to mid 70-percent range.

There are periods of hot, dry weather associated with continental highs. During these infrequent spells humidities are low and temperatures are high. Maximum temperatures of more than 85 degrees F may occur on the average of 1 to 4 days per summer. Extreme temperatures along the North Sea coasts are in the low to mid 90's.

Autumn brings a gradual return to hazardous winter conditions. September is closely related to summer while November begins to feel like winter. Often a brief return to pleasant summer-like weather occurs for a week or so in September or early October. This is similar to Indian Summer in the United States. As storm intensity and size increases and days shorten, temperatures begin to fall. Daytime maximums fall from the upper 50's and mid 60's (degrees F) in September into the 40's by November. Minimums fall from the upper 40's and low to mid 50's into the 30's. By October, temperatures begin to fall below freezing on 1 to 2 days in many locations; this increases to as many as 12 days by November. Lowering temperatures bring an increase in relative humidities, particularly minimum relative humidities. Afternoon minimums, which were in the low to mid 70's (percent) in early fall, rise into the low to upper 80's by November. Maximums already in the 80's increase by 4 or 5 percent in most locations. Increasing relative humidities and falling temperatures accompany an increase in fog frequencies along most coasts. Visibilities in early fall are excellent along the exposed coast of Scotland, where they fall below 5/8 mile on less than 2 days per month. Along the English coasts the frequency of poor visibilities increases during the fall; by November visibilities less than or equal to 5/8 mile can be expected on 3 to 8 days. Along the coasts of the Low Countries and Germany fog occurrences reach a peak from October through January. Low visibilities can be expected on 6 to 9 days each month. Fog frequencies decrease in Denmark and Norway; visibilities of 5/8 miles or less occur on 3-5 days per month along the Denmark coast and 1 to 2 days per month on Norwegian shores. The chances of land fog are always increased by clear conditions. Clear skies (less than or equal to 2/8) are seen more often in fall than summer. They are observed on about 4 to 12 days per month and are most frequent in the Netherlands. Cloudy skies are also observed more often as fall turns toward winter. North Sea coastal residents of Norway, Denmark, and Belgium can see cloudy conditions (cloud cover greater than or equal to 6/8) on about 20 to 24 days per month in fall. Elsewhere, these conditions occur on 15 to 22 days per month by late fall. Rains along most coasts are heaviest in late summer and early autumn. Average amounts are largest along the southwest coast of Norway where they range from 5 to 9 inches in the peak month. Along other coasts this range is from 2 to 3 inches. These amounts tend to decrease somewhat as winter approaches. However, rainy days increase from 10 to 16 days in early fall to 12 to 20 days by late in the season. There is a chance of snow by October in the north and by November in the south.

THE SKAGERRAK AND KATTEGAT

EXTRATROPICAL CYCLONES

A nearly continuous stream of lows and fronts move through or near the Skagerrak and Kattegat producing a variety of day to day weather. These storms are strongest in autumn and early winter. Most pass to the north, but still influence the weather with their large circulations and fronts. The winter storms that move directly through the region bring strong, variable winds and rain or snow. Fronts move through on the average of once or twice a week except occasionally when a large high pressure system intrudes. In winter and spring these fronts sometimes become stationary causing prolonged periods of cloudy, rainy weather. Stationary fronts in the Skagerrak often trigger storm development.

While early winter storms are usually the most potent, the greatest number of lows that pass directly over the region occur in spring and summer. If these lows stall they can produce several days of poor weather. This is less likely during these seasons with the weakening of the blocking Siberian High. Stalling is most likely to occur when a low pressure system occasionally drifts northward from Poland. Lows and fronts in spring and summer are usually characterized by narrow bands of showers followed by rapid clearing. These showers are often heavy.

WINDS-THE SKAGERRAK AND KATTEGAT

Along the Norwegian coast from Kristiansand to Oslo, fall and early winter winds roughly follow the coastline. Northeasterlies are common but not predominant. Winds from the west through north are also common. At Oslo from November through February north and northeast winds prevail but are often secondary to calms both in the morning and afternoon. Calms are also frequent at Kristiansand. February winds become even more complex as the frequency of winds from the southerly quarter increase. Average wind speeds range from 2 to 4 knots at protected ports up to 10 to 12 knots at more exposed locations. Winter winds along the Kattegat coasts and the eastern shore of the skagerrak

assume the more familiar southwesterly through westerly flow. However, easterly and northeasterly winds are quite common. At Stromstad and Goteborg calms are a frequent occurrence. In fact at Goteborg morning calms occur 20 to 30 percent of the time from July through May and 15 to 20 percent of the time in the afternoons from November through March. In general, wind speeds average 5 to 10 knots in winter. At Skagen, this average is about 13 knots.

Southerly through westerly winter winds are also common in the Sound, the Belts and the entrance to the Baltic. Along the shores of the Baelterne (Belts), fall and winter winds are spread mainly between the southeast through northwest at average speeds of 4 to 12 knots. Along Kiel Bay winter winds blow at an average speed of 8 to 10 knots, often out of the south through west. On the coast of East Germany southeast through west winds at an average 10 to 13 knots are common.

Beginning in February and continuing through spring the already variable winds become more variable and average wind speeds begin to show a diurnal variation. As the days become longer and less cloudy the land-sea breeze effect deflects existing winds and at times prevails. At Oslo southerlies and southwesterlies are more frequent particularly during the afternoon. Easterly winds are felt more often along the Norwegian coast. Average speeds range from 2 to 8 knots in the morning and from 4 to 10 knots in the afternoon. Along the eastern shores of the Skagerrak and the Kattegat morning easterlies become more common as do afternoon winds from the southwest through northwest. Northeasterlies and easterlies are more frequent along the western shores of the Kattegat during spring. In general, southwesterlies and westerlies are still the most common winds along the shores of the Kattegat and to the south, particularly in the afternoon. In the Sound and the Baelterne (Belts), the tendency is toward an increase in morning winds off the land and afternoon winds off the water. At Kobenhavn in May, for example, northwest through north morning winds diminish and southerlies and southwesterlies increase in frequency by afternoon. On the coast of East and West Germany, southeast through south winds become less frequent during the day while westerlies and easterlies are on the increase. Wind speed averages in general range from about 4 to 8 knots in the morning up to 5 to 12 knots during the afternoon.

Land and sea breezes are most effective from about May through September. They often prevail and at other times deflect existing flow. They can strengthen or weaken this existing flow but on the average wind speeds are stronger in the afternoon than they are in the morning. The sea breeze is the more influential of the two. For example, summer winds up Oslofjord in the morning are a struggle of opposing forces with southerlies, northeasterlies and calms in the battle. By afternoon, there is little doubt as to the prevailing wind. At Oslo, southerlies and southwesterlies rule. The sea breeze effect from Kristiansand to Faeder is complicated by the fact that it is perpendicular to the prevailing wind. It is, therefore, most noticeable on quiet summer days. At these times an easterly breeze will develop shortly after sunrise and will gradually veer through the day ending up from the southwest by late afternoon. This progressively varying wind is known locally as "Solgangsver."

From Oslo southward along the east coast of Sweden the story is the same. In the morning southwesterlies and westerlies are most frequent, followed closely by calms and easterlies which are generated by the land breeze. By afternoon southwesterlies and westerlies dominate the wind picture as a result of the sea breeze, the prevailing wind and the combination of both. The sea breeze is less effective along the Kattegat's western shore since it opposes the normal prevailing flow. In the Baelterne and The Sound southwesterly and westerly morning winds either increase or decrease in frequency during the day depending on the direction of the sea breeze. It usually coincides with the prevailing directions, however. In some cases, the sea breeze reroutes the prevailing wind to the south or southeast. The average wind speeds increase by 2 to 4 knots during the day with afternoon speeds averaging 8 to 12 knots.

Along the shores of Kiel Bay, the sea breeze seems to play a secondary role to the prevailing southwesterly to northwesterly flow. The pure sea breeze when conditions allow comes into Kiel from the northeast and more from the east or north at other locations. Summer winds on the East German coast, leading to the Baltic, show an increase in winds off the water during the day with a decrease in land breezes. For example, at Wustrow, westerlies which are the most common morning wind nearly double in frequency by afternoon. Average wind speeds reach a peak of 8 to 10 knots in the afternoon.

GALES-THE SKAGERRAK AND KATTEGAT

The relative infrequency of coastal gales makes them more dangerous when they do occur. Gales in this region occur on from 1 to 20 days annually while wind speeds between 28 and 34 knots are much more frequent. At Kobenhavn for example, winds of gale force occur on the average of just 2 days annually while winds equal to or greater than 28 knots occur on 26 days in an average year.

The most dangerous coastal gale in the Skagerrak occurs in southeastern Norway where it is known as the "Sno" or "Elvegust." This winter wind has been known to drop temperatures by 30 degrees F. It is a cold mountain outflow that streams down valleys and fjords. It is a strong, gusty wind that often occurs on clear days and builds to gale force within

a few hours. Shelter is often found in tributary fjords when main fjord winds are strong. These winds are particularly strong in narrow channels or around projecting headlands. Gales along the Norwegian coasts are most likely to occur with the most frequent wind direction. Oksoy is one of the most exposed ports and gales blow on the average of 2 to 3 days per month from October through March. Oslo is a well-sheltered port where gales occur on the average of 1 day a year. When gales blow from the southwest or west the winds in Oslofjord are usually 10 to 15 knots lighter than along the Skagerrak coast. Southerly gales, however, expose Oslofjord.

Southeasterly gales are strongest along the southern tip of Norway. Just off Skagen, on the northern tip of Denmark, winds equal to or greater than 28 knots blow on an average of 5 to 6 days per month from October through March.

Along the Kattegat coasts the occasional northwesterly winds of winter and early spring can be dangerous. In the violent squalls that sometimes accompany these winds a vessel may find itself against a lee shore, owing to a sudden wind shift, at a time when heavy snow obscures all landmarks. The easterly winter wind can also be dangerous particularly in the eastern approaches to the Kattegat. In exceptionally heavy weather it can reach 50 knots and be accompanied by snow and intense cold. These winds are generated by a buildup in high pressure over the Soviet Union and Scandinavia, so are just as likely to be preceded by a rising as a falling barometer. Strongest winds along the West German coast blow most frequently from a south through west direction, and gales occur on the average of 1 to 4 days per month from October through May. In general, winds are strongest in the southern part of the Baelterne leading to the Baltic. At Marstal, for example, winds reach 41 knots or more on 1 to 3 days per month from September through March while Samso and Goteberg have 2 to 3 days with these winds each year. The open waters of the Kattegat are more exposed to strong winds than the coasts. Gale-force winds are infrequent from May through August when they are occasionally generated by a thunderstorm.

VISIBILITY-THE SKAGERRAK AND KATTEGAT

Fog and poor visibilities are least frequent over the open waters of the Skagerrak and Kattegat. In the confined waterways of The Sound, Baelterne and the numerous fjords, fog provides a hazard to already hazardous navigation. The fog that produces these visibilities occurs most often from Autumn to Spring with a maximum period in winter. It is a land fog that develops under clear skies and light wind, and then drifts out over the water. Because of the lack of sunlight in these seasons it does not dissipate rapidly. Inland, it occurs as cold air from the highlands drains down into the fjords under quiet conditions. Winter fog may also form when sea ice cools a warm damp southerly flow or when a light cold wind blows over relatively warm water. Good visibilities are most frequent when strong northerly winds bring an Arctic flow over Europe.

Along the coast of Norway visibilities drop below 5/8 miles on 2 to 5 days per month from October through April. At Oslo these visibilities occur on 3 to 12 days per month from September through April with the maximum occurring in December and January. In general, most fjords have a fog frequency similar to Oslo's. At Skagen fog occurs on 2 to 6 days per month in every month but August. Along the shores of the Sound, fog is prevalent from September through April when it occurs on about 4 to 12 days per month, reaching a peak from December through March. Although there is little diurnal variation fog is most likely during the morning hours. Through the Baelterne fog occurs on about 3 to 10 days per month from September through April. Along the north coasts of East and West Germany fog is also reported on 3 to 10 days per month with a peak in late fall and early winter.

Summertime brings good visibilities to almost the entire region. Radiation fog can form in the morning hours if clear quiet conditions have prevailed during the night. However, this fog is quickly dissipated by the rising sun. Most susceptible to summer morning fogs are Skagen, Oksoy and Samso.

CLIMATE-THE SKAGERRAK AND KATTEGAT

Late fall and early winter brings the worst weather to the Skagerrak-Kattegat area. The procession of fronts and storms keeps winter skies under an almost continuous blanket of clouds with many days of light rain or drizzle. The shortness of the day adds to the bleakness and aids in keeping temperatures steady. Low temperatures with a small diurnal range bring high relative humidities over much of the area. Inland ports, up fjords and rivers, experience more radical changes in weather than do coastal ports. Temperatures vary more as do relative humidities, cloud cover and precipitation.

Weather patterns are depressingly redundant from October through January. Cloudy conditions (cloud cover greater than or equal to 6/8) can be expected on about 15 to 25 days per month. They are most common in the Sound and least frequent along the shores of the Skagerrak. However, fall and early winter is the rainy season along the Norwegian coast where 4 to 7 inches of precipitation per month fall on 10 to 15 days. Outside of Norway, 1 to 3 inches occur on 8 to 12 days under cloudy skies. Some of this precipitation falls as snow. Temperatures get below freezing from October through April or May. Freezing temperatures are most common in continental situations along the German coasts, Sweden, northern Denmark, and Norway. In general, nighttime lows can be expected to fall to freezing or below on 15 to

26 days per month in mid winter. During this season relative humidities are high with practically no diurnal variation. The average spread is about 5 percent at most. Morning maximums in January range from 85 to 92 percent, while afternoon minimums range from about 80 to 90 percent. Snow can occur from about October through May and is most probable in December, January and February. The probability of snow decreases southward through The Sound and the Baelterne but picks up slightly along the East and West German coasts. The continental port of Oslo records snow on 61 days in an average year. This drops to 50 along coastal Norway and to about 40 near Goteborg. In the Baelterne, 20 snow days occur on the average and this increases to near 30 days at Rostock. January is usually a good snow month since temperatures are coldest. Daytime maximums are in the mid 30's (degrees F) except at inland ports like Oslo where the average January maximum is 27 degrees F. Nighttime lows range from 25 degrees to 30 degrees F along the coasts to the upper teens up fjords and rivers. Extreme low temperatures occur under clear skies when the Siberian High occasionally pushes over the area bringing a frigid easterly flow. Clear conditions (cloud cover less than or equal to 2/8) are observed on 1 to 7 days per month in January. When conditions are right temperatures can plummet to zero and below. Extremes range from -5 degrees F at exposed ports to -20 degrees F at more continental locations.

By February changes in the weather patterns are already taking place and this is reflected in the average conditions. As days become a little longer and skies a little clearer, temperatures begin a slight upward trend that becomes more apparent in March when average temperatures increase 2 degrees to 6 degrees F. The number of cloudy days decrease. February marks the beginning of a relatively dry season that extends through May. Precipitation amounts average 1 to 2.5 inches on about 5 to 12 days per month. Temperatures show their greatest rise in April and May. This results in a decrease and more of a variation in relative humidities. Morning ranges run from about 75 to 88 percent while afternoon humidities drop to the low 50 to mid 70 percent range.

As spring melts into summer cloudiness continues to decrease, temperatures rise and humidities fall. But rainfall amounts increase. Outside of Norway's autumn maximum, average rainfall amounts are largest in August. Midsummer amounts range from 2 to 4 inches mostly in showers and thunderstorms on 10 to 14 days per month. Instability needed for shower activity is produced by frontal passages and surface heating. Heating alone is usually not enough along these coasts. By July, average maximums are around 70 degrees F; slightly cooler at exposed ports and slightly warmer at more sheltered locations. Even at a continental port like Rostock, July temperatures get above 76 degrees F on only about 7 days.

Thunderstorms are most often associated with frontal passages from May through September. Along Skagerrak shores, they occur on just 6 to 8 days each season; Oslo records an average of 11. They are slightly more frequent along Kattegat coasts, particularly near the entrance to the Sound; 6 to 10 days with thunderstorms can be expected in an average year. It is south of the Kattegat that thunderstorms are most likely. Along the shores of Kiel Bay and Mecklenburger Bucht they occur on 12 to 20 days annually and 2 to 5 days per month from May through September. Along the shores of the Lille Baelt (Little Belt), thunderstorms are recorded on 8 to 15 days annually and in the Great Belt and Sound this figure drops to 10. Thunderstorms and showers are often responsible for heavy rainfall amounts in a short period of time. Record 24-hour amounts most often occur in the summer and run 2 to 4 inches. Even with this rain, clear conditions (cloud cover less than or equal to 2/8) are at a peak in May, June and July; about 5 to 10 days per month are clear.

Cloudy conditions (cloud cover greater than or equal to 6/8) are at a minimum from May through September: however they still occur on 6 to 14 days per month. September is the least cloudy month south of the Kattegat. The lack of cloudiness helps create a wide temperature spread as 70 degrees F daytime readings fall into the low 50's at night. This in turn is responsible for a wide spread in relative humidities. These humidities vary from the low 70 to upper 80 percent range in the morning down to the 60 to 70 percent range in the afternoon. Humidities can drop to extremely low values when, occasionally a hot dry flow off the continent engulfs the area. This is most likely in late summer and can send temperatures soaring into the 80's or above. Extreme temperatures range from the low to upper 90's in continental locations down to the low 80's over coastal Norway. Oslo's continental location is reflected in its extreme of 93 degrees F.

BALTIC SEA

EXTRATROPICAL CYCLONES

The day to day weather along the Baltic shores is produced mainly by the low pressure systems that move through or near the area. These storms are largest and most intense in late autumn and early winter. Most come from the Atlantic and the most intense are those that move eastward across Denmark and then northeastward across southern Sweden into Finland. The secondary Skagerrak Lows can also become intense in the Baltic. Winter storms blocked or forced northeastward by the mountains of Scandinavia are often large enough to bring a southerly to southwesterly flow over the Baltic. The occasional storms that move into the area from the Barents Sea bring bad weather to the entire Baltic Sea. Spring and summer lows are less intense but can trigger heavy showers and thunderstorms along the Baltic

coasts. Most of these come from the west. Some stall east of Stockholm and cause extended periods of clouds and rain. Occasionally shallow, summer lows drift northward from Poland and bring periods of heavy rains.

WINDS-BALTIC SEA

A general south through west flow is prevalent along Baltic shores from September through January or February. At some ports, like Riga and Klaipeda, topography is responsible from a high frequency of southeast winds, in addition. These winds are mainly the result of large storm systems moving to the north. Variability is introduced when storms move through the Baltic. Fronts passing through often bring a following northwesterly flow, while large highs from off the continent bring easterly winds. Day to day winds are variable but there is little regular variation in direction or speed. Average wind speeds range from 6 to 10 knots. Even more variable are the winds of spring. At many locations this change is noticeable by February. In March, there is an increase in the frequency of north through east winds. Morning winds, at some locations, are variable in direction. The land-sea breeze begins to take hold in March. In calm weather it dominates but more often it acts to deflect and either strengthen or weaken existing flow. Ports with a western exposure to the Baltic, like Klaipeda, are subject to an afternoon increase in southwesterly through northwesterly winds and a decrease in north through east winds. Along the southern Baltic coast at a port like Swinoujscie, the frequency of northerlies and northeasterlies become more prevalent during the day while southerlies and southwesterlies fall off. Wind speeds in spring and summer also show a significant diurnal variation. Average speeds range from 4 to 8 knots in the morning and 10 to 12 knots during the afternoon.

GALES-BALTIC SEA

Along the Baltic coasts an encounter with strong winds is most likely from October through March. At exposed ports, gales occur on up to 5 days per month from November through February while at a protected port like Stockholm gales occur on less than 5 days in an average year. Winter gales most often ride southwest winds. In spring gales from the northeast may be encountered when a low moves across Poland, from the Adriatic Sea, and pushes up against a large high over Scandinavia. In general, gales can be expected on 2 days per month or less from May through July. Summer gales are often from the northwest. Also thunderstorms and squalls may produce brief gusts of gale force. Ports most susceptible to summer gales include Klaipeda, Riga and Kalmar.

CLIMATE-BALTIC SEA

Autumn through early winter are the worst times along Baltic shores. Rainy, foggy days, cool temperatures and clouds abound. Spring and early summer-these are the best times; skies are blue, visibilities are good, temperatures are mild and rain is infrequent.

Shorter days and cloudy skies bring an ominous look to the Baltic in Autumn. Those cloudy days (cloud cover greater than or equal to 6/8) which numbered less than a dozen in September become more and more frequent, until by December their number has grown to 18 to 22. Clear days (cloud cover less than or equal to 2/8) occur just once or twice in December. Under these cloudy skies, rain and snow become frequent. While amounts average just 1 to 3 inches, they occur over a period of 8 to 14 days per month. At Riga, for example, precipitation falls on 12 to 14 days per month from August through November. Beginning in October, this could occur as snow. Early and late season snows usually melt upon reaching the ground. The real snow season is from December through March. Below freezing nighttime temperatures are common by October. The following month, average nighttime lows are around the freezing mark with average daily maximums in the low 40's (degrees F). This range of temperatures shortens the wide summer range of relative humidities while the decreasing temperatures help raise humidities. By November, early morning readings are in the 84 to 92 percent range with afternoon humidities dropping into the low to mid 80's (percent). When humidities are high, nighttime skies are clear, and conditions are calm, there is an excellent chance of fog. The rapidly cooling land produces a radiation fog which often drifts out over coastal waters. Fog may also form when a mild flow of warm moist air moves over cooler waters. At Kalmar and Stockholm, this occurs with south and west winds during fall and winter. Snow and rain add to the poor visibilities, which are at their worst from October through March. Riga averages 6 to 11 days per month during that period.

January and February are the coldest months along the Baltic coasts. Extreme low temperatures can occur during this period if a large high moves off the continent and brings a frigid easterly flow over the Baltic. Recorded extremes range from 6 degrees F at Sandvig down to -24 degrees F at the continental, Kalingrad. Usually minimum temperatures fall below freezing on 20 to 26 days per month; their average ranges from 20 degrees to 30 degrees F. Daytime maximums range from 29 degrees F at Riga, to 37 degrees F at Sandvig. An average temperature spread of 7 degrees to 9 degrees F results in a 2 to 4 percent diurnal variation of relative humidities in December and January. Early morning maximum relative humidities average in the upper 80 to low 90 percent range and afternoon minimum range from the mid to upper 80's. Frequent days of light rain or snow continue through the winter. Average measurable amounts of 1 to 2 inches fall on 8 to 10 days per winter month. Snow occurs on about 7 to 14 days per month from December through

March and on more than 2 days per month from November through April. Precipitation often falls under cloudy conditions which occur 15 to 22 days per month from November through February. Clear skies are seen on just 1 to 3 days per month during this period. Fog is still common and occurs on 2 to 10 days per month at most locations.

In early spring, fogs often occur when warm, moist air moves over cooler water or melting ice. These fogs may be patchy. By late spring, fog becomes more infrequent and skies in general become clearer. The skies are clearest from May through September along the Baltic coasts. At Visby, for example, in an average June, there are 5 cloudy days and 9 clear days. Along with this improvement is the decline in rainy days. Minimum rainfall amounts of less than 2 inches usually occur in February or March. Rain falls on only about 6 to 8 days per spring month and snow is rare by May, as are freezing temperatures. Average nighttime minimums are up to the mid 40's (degrees F) by May. Daytime highs climb from around 40 degrees F in March to the upper 50's and mid 60's by May. This influences relative humidities which average from the low 70 to mid 80 percent range during the morning and down to the mid 50 to mid 70 percent by afternoon.

Summer days are warmest, on the average, in July and August, when under partly cloudy skies temperatures climb to around 70 degrees F and relative humidities fall into the 60 percent range. Sometimes if it warms up enough, an afternoon shower or thunderstorm may develop on the coast. Showers occur on 8 to 12 days per month and become thunderstorms on 2 to 4 of these days. Showers can also be triggered by fronts moving through the Baltic. They bring amounts totaling 25 inches per month on the average. At times, these showers can be heavy and maximum 24-hour amounts range from 2 to 4 inches along Baltic shores. Temperature extremes occur when hot, dry air flows off the continent. Record highs range from the upper 80's to upper 90's (degrees F). Summer nights are pleasant as temperatures drop into the mid 50's while humidities climb to the 75 to 90 percent range. Early morning fog is a possibility under clear nighttime skies at the more continental ports. This is usually a shallow land fog which dissipates soon after sunrise.

GULF OF BOTHNIA AND GULF OF FINLAND

EXTRATROPICAL CYCLONES

The Gulfs of Bothnia and Finland are shielded from many storms by the mountains of Scandinavia. Most storms move into the area from the south through west. Large winter storms to the west and north of Norway are effective weather producers in the Gulfs. They also can trigger Skagerrak Lows which may move through the area bringing strong, rapidly shifting winds. Lows that move directly over the Gulfs are often more frequent in spring and summer. They are, however, weak shallow systems with narrow bands of clouds and showers.

WINDS-GULF OF BOTHNIA AND GULF OF FINLAND

Along the shores of the Gulfs of Finland and Bothnia, the winter wind regime becomes established in November and breaks down in March. Wind directions on both shores of the Gulf of Finland and on the eastern shore of the Gulf of Bothnia vary mainly from southeast to southwest at a average of 7 to 14 knots. There is little diurnal variation in either direction or speed on these short days. Along the east coast of Sweden topography interferes with this prevailing flow and at many ports it becomes secondary to northerly winds caused by cold air flowing down the mountains. Wind speeds are also less and run 5 to 8 knots on the average. An extreme example of sheltering occurs at Harnosand, Sweden where from November through February calms occur about one-half of the time. Come February, there is a noticeable increase in northeasterly winds along all coasts and more variability in general. At Helsinki, northerlies and northeasterlies are the two most common directions in February. As days grow longer the sea breeze alters prevailing flow and along all coasts there is a noticeable increase in onshore components from morning to afternoon. The sea breeze influence is also reflected in the wind speeds, which increase from 7 to 10 knots in the morning to 10 to 12 knots during the afternoon.

The land-sea breeze effect reaches a peak in summer. Morning winds tend to be variable, particularly when the land breeze comes from a different direction than the normal flow. At Hanko, Finland, for example, normal flow is from the south through southwest while land breezes, which occur when normal flow is slack, are from a northerly direction. The result is that in July, at Hanko, morning directions that occur 10 to 14 percent of the time include north, east, southeast, south, southwest, northwest and calm. Sea breezes can strengthen or sometimes can reverse existing winds. Therefore the variable, light winds of morning give way to a preponderance of off-the-water breezes during the afternoon. Northerly components are common along the south shore of the Gulf of Finland, and southerly components along the north shore. In the Gulf of Bothnia, westerly components are prevalent in the afternoon along the eastern shores while easterly components are found on western shores. Morning wind speeds that average 7 to 9 knots increase to a 10 to 13-knot range in the afternoon. September remains very much like summer with sea breezes still evident and morning winds still

variable. There is an afternoon increase in wind speed but it is just slightly less than it was in midsummer. This wind speed increase is even less noticeable in October while more and more the prevailing winds tend to remain the same all day.

GALES-GULF OF BOTHNIA AND GULF OF FINLAND

Gales are infrequent along the shores of the two Gulfs. The most exposed coast lies between Tallinn and Vyborg. Winds reach 30 knots or more on from about 20 to 40 days annually. These winds are most likely from fall through spring and can occur on up to 5 days per month in winter. When a large winter Siberian high pushes westward, cold, strong easterly winds can blow without let-up for several days. The coasts of Finland and Sweden are sheltered from strong winds. At Helsinki, gales just don't occur and Haparanda hasn't recorded a wind of 41 knots or more in 16 years of observations. In general, gales along these coasts occur on less than 10 days a year. Umea is one of the more exposed locations and winds of 41 knots or more occur on 9 days annually.

CLIMATE-GULF OF BOTHNIA AND GULF OF FINLAND

The climate of the Gulfs of Bothnia and Finland, particularly the eastern Gulf of Finland and northern Gulf of Bothnia, is more continental than that of the other regions. This means a greater temperature range and more snow. The region is sheltered somewhat by the mountains of Scandinavia, which results in scanty precipitation amounts.

Late autumn and winter weather is the worst and along with the ice practically prohibits navigation of these waters. The first snow usually occurs in October and the last in early May. From November through March snow falls on 10 to 20 days per month except near the entrance to the Gulf of Finland where 5 to 10 snow days per month can be expected. From December through March, snow depths can reach 20 to 30 inches along the northern Gulf of Bothnia coasts and the eastern shores of the Gulf of Finland. Maximum daily temperatures in these areas usually remain below freezing from November through April and mid-winter minimums fall to about 4 degrees to 12 degrees F on the average. Shores along the entrance to the Gulfs of Finland and Bothnia are moderated somewhat by the warmer Baltic waters. Extreme temperatures range from -10 degrees F at these entrances to -40 degrees F in the eastern and northern reaches of the Gulfs. The low temperatures bring high relative humidities with little diurnal variation. Skies are cloudy from late summer through early spring. December is the grayest month; cloudy conditions (cloud cover greater than or equal to 6/8) can be expected on up to 26 days at Tallinn and Leningrad. Clear conditions (cloud cover less than or equal to 2/8) are infrequent at any time of the year. Snow and fog are responsible for poor winter visibilities. Heavy snow, even in high winds, can reduce visibility to a few yards. Blizzard conditions can occur in this region. Winter fog is often the type which forms when cold air blows off the land or ice, over relatively warmer waters. This is called sea smoke and is most frequent in autumn. Poor visibilities are most likely along the Gulf of Finland shores. From September through April, visibilities fall below 5/8 mile on 4 to 8 days per month on these shores and on 2 to 5 days per month along Gulf of Bothnia coasts. Best visibilities are encountered along the Swedish coast.

Spring is a season of moderating temperatures, clearing skies, and fewest days with precipitation. Summer brings pleasant temperatures, showers and partly cloudy skies. Spring and summer are the least cloudy seasons along the shores of the Gulfs of Bothnia and Finland. Clear conditions occur on up to 4 to 8 days per month while cloudy conditions are observed on as few as 6 to 12 days per month. Best conditions occur during May, June and July when shallow lows bring narrow bands of clouds and showers. Showers and thunderstorms are responsible for much of the spring and summer rain. Totals are usually greatest in August with averages of 2 to 3 inches. These showers can reduce visibilities briefly, but in general, visibilities at ports improve during the spring and are best in June and July. This is not true over open water and at entrances to ports where mild winds blowing over cooler waters cause considerable fog in summer. The fog at ports usually forms in the early morning and is quickly burnt off by the increasing temperatures. Temperatures on summer afternoons rise above 70 degrees F from about May through September but mostly in July when they get up over 70 degrees F on 10 to 20 days.

Temperature rises begin in March and continue through July. Biggest rises occur from March through June when average daily maximums increase from the upper 20's (degrees F) and mid 30's to the low to mid 60's and average daily minimums increase from the teens and low 20's to the mid to upper 40's. During this same period, relative humidities drop off and their diurnal variation becomes greater. By June, maximums in the 70-percent range and minimums into the 60-percent range are common. July is usually the warmest month; average daily maximums range from 65 degrees to 75 degrees F while minimums run from the low to upper 50's. Extremes are most likely in June, July or August when temperatures from the mid 80's to upper 90's have been recorded. Lows in midsummer have dipped below freezing at only a very few ports. Freezing temperatures usually occur last in May and start again in September. Days with snow, therefore, do not occur from June through August. Rain, however occurs on about 6 to 12 days per month during this period and thunderstorms can be expected on 1 to 4 days per month from May through September.