Environment Canada Environnement Canada

Wind, Weather & Waves

A Guide to Marine Weather in the Great Lakes Region

Second Edition

Canada

Acknowledgments

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Knowing the Elements

"The Great Lakes sailor is wild-ocean nurtured; as much of an audacious mariner as any."

– from Moby Dick, by Herman Melville.

"One of the problems that people who are not used to the Great Lakes have with them is that we call them lakes... We're talking about water surfaces of something like a quarter million kilometers – that's oceanic levels. That's not just lakes, that's inland seas. If we thought of the Great Lakes as inland seas, we'd probably treat them with more respect."

– Peter Trueman.

General Information

Whether in calm or churning waters, whether in fog or under fair skies, the Great Lakes present a challenge to boaters that must be entered into with respect, caution and humility. Their changing moods and scant shelter can make boating – under sail, power or manpower – an exciting and exhilarating experience.

The elements are the very stuff of boating. Out on the waters, nearshore or offshore, wind, weather and waves combine to test your skill as a boater. Developing a keen weather sense is as crucial to arriving home safely as is the soundness of your craft or the strength of your navigation skills.

This book will help you get the weather information you need and focus your weather eye. It is intended as a practical guide to the ins and outs of marine weather in the Great Lakes region. Many of the principles discussed can also be applied to other waters, but our emphasis is on the "inland seas" that offer limitless pleasure to boaters, and on smaller lakes and waterways in the Great Lakes region.

These remarkable inland seas stir up strange brews of weather and water. They are highly variable, subject to both maritime and continental influences, and, although summer weather is usually hospitable to recreation boating, from time to time they experience the ferocity of both isolated thunderstorms and vast weather systems. Conditions can change quickly; they can range from calm to tempest over a very short time or distance. And the great variety of marine traffic, from sailboards to ocean vessels, creates additional hazards.

Both the "old salt" and the novice boater need to be alert to weather. It takes a skilled mariner to master the Great Lakes; and the true master knows when the lakes and the weather should not be challenged. The joys of boating are many, but the risks should not be ignored. A lack of respect for the elements may have tragic consequences. Theirs is a long history of tragedy, for vessels of all sizes and types, on our 'inland seas'.

We want to encourage you to value and cultivate a weather eye, both to increase your enjoyment (knowing how to catch the wind and ride the waves) and to anticipate and avoid risks. This book provides a guided tour through the elements, pointing out what to watch for and how to interpret it, with many full-colour illustrations.

We will equip you with the information and inspiration you need to enjoy fine tuning your weather senses (in **Weather, Wind, Waves, and When the elements rage**, at the front of the book), as well as details on what to do in an emergency **(Marine emergencies, in the middle of the book)**.

Environment Canada, Transport Canada and the Canadian Coast Guard make available a wide range of products and services to help you be alert to and understand weather on the Great Lakes. These are laid out at the back of the book, in **Working together.**

But, in the Great Lakes region, local conditions vary greatly and, to help you integrate all the information in this book and adapt forecast information to your location and circumstances, we have also included a guide to **Local conditions**, towards the back of the book.

We invite you to read the entire book at your leisure, paying special attention to conditions in your area and the information sources you will need to use. Then, stow it away in your boat for easy reference whenever the elements present a challenge.

Good luck and happy boating!

"Canoeing and kayaking accident reports consistently note carelessness or ignorance as the primary cause of fatalities, and lack of rescue skills as a secondary factor. Rolling and out-of-boat rescues are at best symptomatic treatments ... they are not substitutes for knowledge of weather, waves, currents, rules of the sea and our personal limits.

If we taught paddlers to exercise caution first and rolling and rescues later, we would be much closer to our goal of making paddling safer and more enjoyable."

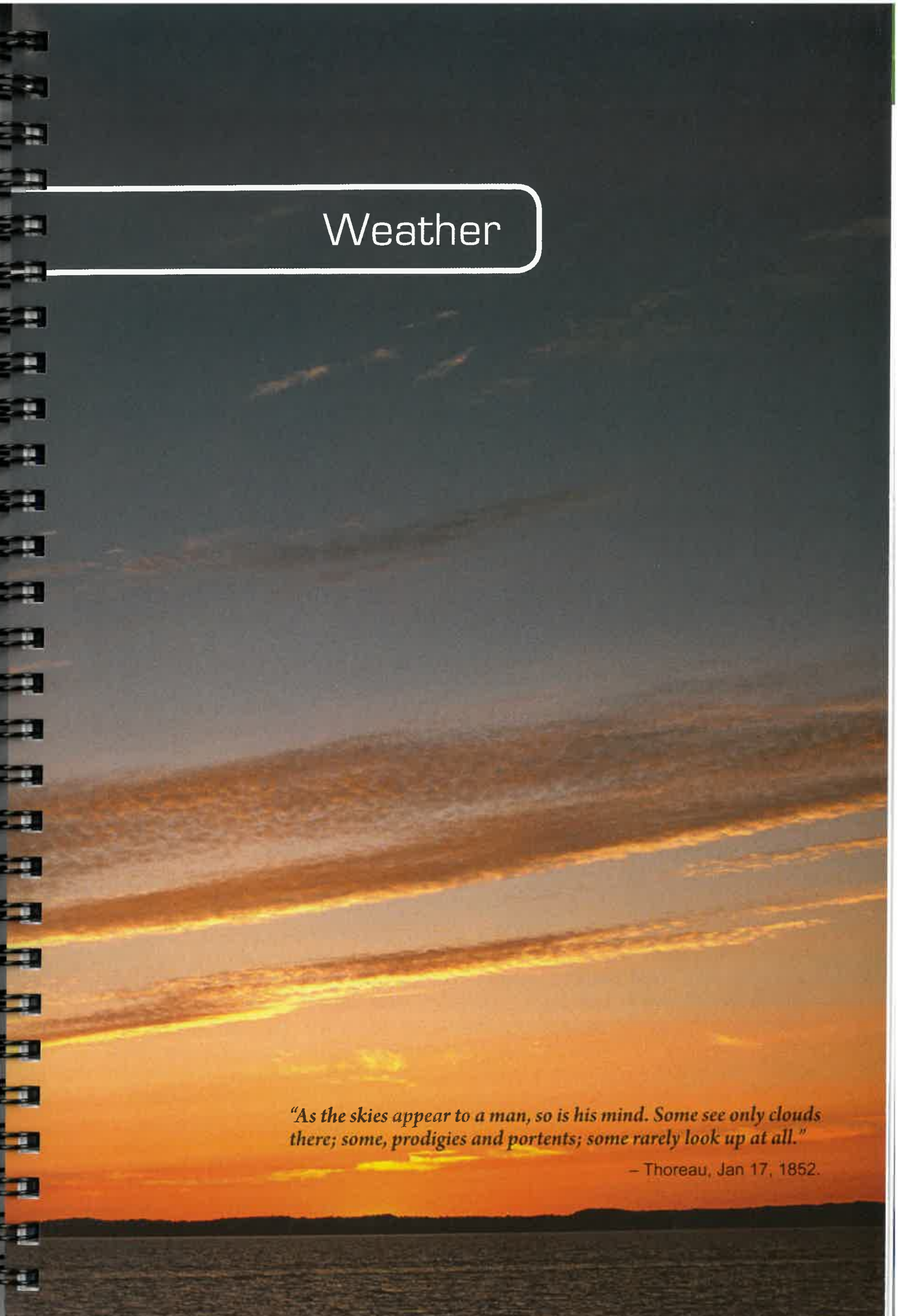
John Winters, in QAYAQ, Spring 1997.

"Overconfidence can be a problem. We thought we could just take off from Leamington and head out past Point Pelee, no problem. ... But as soon as we turned the point to go east, the waves were no longer behind us. They were broadside and they were mounting to 6 and 8 foot waves. And it was kind of hairy for the first day."

– Lake Erie sailor.

"In the Great Lakes the weather conditions can change so fast. It can change from glass flat to four foot swells in five minutes time."

– Lake Ontario boater.



Weather

"As the skies appear to a man, so is his mind. Some see only clouds there; some, prodigies and portents; some rarely look up at all."

– Thoreau, Jan 17, 1852.

The Atmosphere – Where it all Happens

"The grandest production of collaboration in all of nature."
– Lewis Thomas

An ocean of air

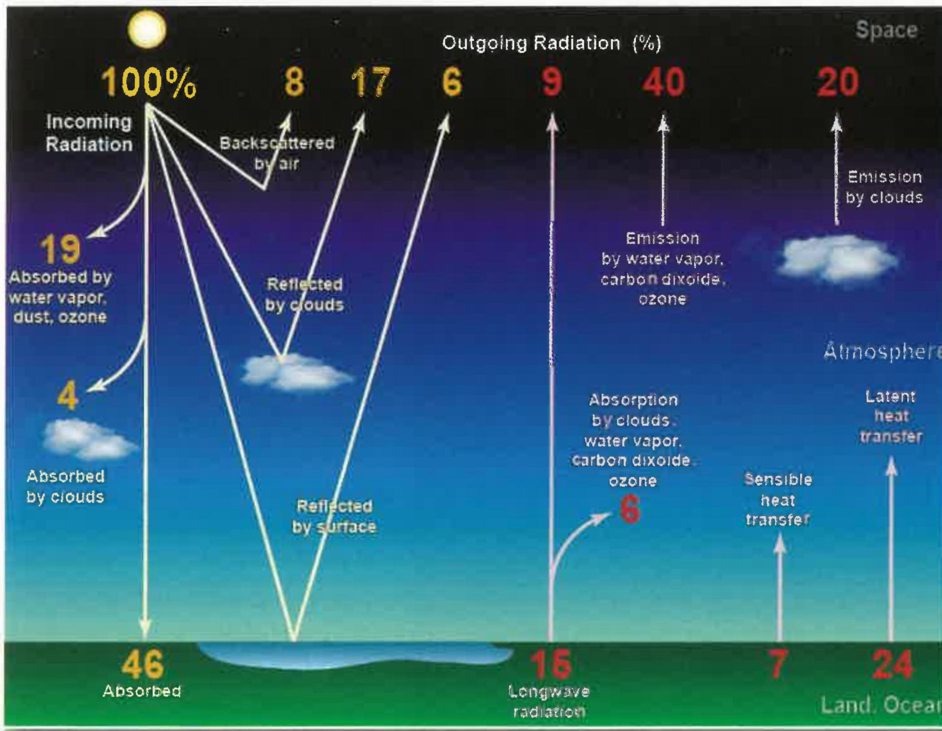
The Earth is enveloped by an ocean of air. Along with the main gases of nitrogen and oxygen, there are many others in smaller quantities, plus water vapour, dust, sea salt, and pollutants. Although the entire atmosphere reaches up several hundred kilometres, half of it by mass is below 6 km because gravity compresses the air down toward the service.

The lowest layer, the troposphere, extends from the Earth's surface up to about 12 km. This is where all of the weather that we experience occurs. It is warm near the surface but becomes colder with height. Above this relatively cold layer is a warmer stratosphere which acts as a natural barrier to rising air from below. Heat and moisture originating at the surface rise to become part of the weather systems or storms but the clouds do no rise beyond this lid. You could say that the structure of our atmosphere keeps a lid on the weather to stop it from going out of control. After all, thunderstorms, which occupy the full height of the troposphere, already pack plenty of punch!

Energy makes the weather go around

The sun's energy does more than set up the atmosphere's temperature profile to regulate vertical air motion. It also provides the warmth we need to survive and the fuel for the planet's weather machine. Most of the high energy (shortwave radiation) from the sun penetrates through to the Earth's surface where it is partly reflected and partly converted to heat (see diagram, below). The heat warms the surface and is stored by the oceans for redistribution. When this heat, a less intense form of energy (longwave radiation), is radiated back toward space by the Earth, much of it is absorbed by clouds and pollutants. Clouds act as regulators of the energy coming in and going out. On cloudy days, much of the sun's energy is blocked from reaching the surface and on cloudy nights the heat from below is largely kept in. Each day, the air in the lower troposphere receives heat from the surface which rises to form clouds and drive our weather systems.

Energy from the sun causes much more heating near the equator than at the poles, creating a global heat imbalance. Persistent rising air in low latitudes and cooled, sinking air in colder

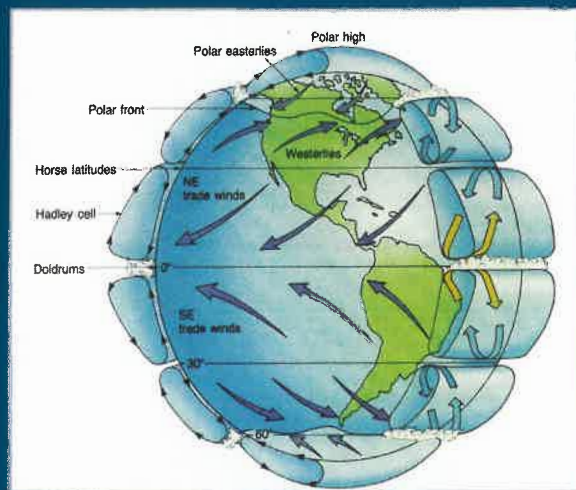


The Energy Balance

Energy from the sun (shortwave radiation, purple lines comes into the atmosphere and is partly reflected back out by the tops of clouds and by the Earth's surface (especially snow cover). The rest is converted to longwave radiation (redlines), much of which remains in the lower atmosphere because the undersides of clouds reflect it back to earth. Clouds also absorb and deflect radiation of various wavelengths. They are important regulators of the incoming and outgoing energy balance, both for the planet and for a particular day in a specific place. Even thin cloud layers can block enough energy to dramatically alter the temperatures and potential for convection at a location.

regions sets a large circulation into motion. If the Earth didn't rotate, the atmosphere would be one giant, simple circulation of cold air draining away from the poles and rising in the tropics to spread poleward again at high altitudes. But when we add spin to our planet, the flow pattern is quite different. Air moving above the surface is affected by the Coriolis force and turns to the right in the Northern Hemisphere. The coriolis effect is a deflective force arising from the rotation of the Earth on its axis. So, instead of air moving north from the tropic, for instance, it turns eastward in the mid-latitudes and sets up a zone of strong westerly winds. This zone is the boundary along which weather systems move. Below a height of about 2 km, the wind direction is controlled by passing weather systems. Above this, a predominantly westerly flow

The global circulation is a complex pattern of alternating low and high pressure belts. The air must cycle through regional circulation cells before it can work its way farther from a source. Air rising near the equator moves poleward and descends in the sub-tropics. From there, part returns to the equator in the trade winds while part spreads poleward and meets arctic air in the westerlies zone. The winds are linked globally, but only through this series of distinct cells or stages.



prevails (usually between southwest and northwest), increasing in strength with height. These westerlies are present over the Great Lakes most of the time and steer the weather systems independent of the winds we experience at the surface.

On a much smaller scale (but with the same principles), local differences in heating lead to local imbalances and smaller variations in wind flow and weather conditions.

Moisture in the air

Water may be a very common, basic substance to us but it is actually quite a strange material. Its molecular structure makes it denser as a liquid than a solid – something that is not true for any other material. This unique property means that ice floats, which is important in regulating temperature extremes. If ice didn't float, lakes and oceans would accumulate ice at their bottoms where it would be much slower to melt. In a really bad winter, the Great Lakes might then fill up entirely with ice and we'd all have to wait until July to get

"Most people learn by experience. Unfortunately some of those experiences can be bad. It would be much wiser for people to take a [Canadian Power and Sail] Squadron course, to study a bit of weather, to understand the conditions before they go out and get themselves into a dangerous situation."

– Marc Raymond, Power Squadron.

on the water! An ice sheet forms an insulating barrier that slows the transfer of heat from the liquid to the cold air. When spring arrives, it melts relatively quickly and the water can begin the steady, though somewhat reluctant, warm-up. The insulating properties of water and ice help to regulate temperature variations and give us a modified climate around the Great Lakes.

Water is the only substance that can change between the solid, liquid, and gaseous states at temperatures normally found at the Earth's surface. When water changes state, there is also a transfer of energy. For instance, it takes energy to evaporate water and that energy is released as heat when the water vapour condenses. The same occurs when water freezes or ice melts. This energy transfer, called latent heat, occurs without a temperature change, so in this way, water acts as an energy buffer. When water freezes, heat is released (latent heat of fusion) and when ice melts, heat is absorbed from the air. Snow and ice resist the spring warm-up by drawing heat out of the air. Similarly, the latent heat of evaporation and condensation will cool or warm the air as water changes from liquid to vapour and back again.

This stored "extra" energy is a vital part of all cloud formation, especially summer convection. As clouds form and grow, the heat released during condensation heats the air inside them. The warmed air keeps on rising and causes the clouds to grow even larger. At the same time, water droplets can evaporate and cool the air, creating downdrafts in other places which balance out the process and establish the up-and-down circulations of summer storms. Changes of state within cloud

A drenching cloudburst cuts through the hot, humid air.

systems set up circulations and wind patterns that also affect what's happening at the ground. The winds we experience on a typical summer afternoon are part of a bigger balancing act in the clouds above us.

Air contains moisture in the form of water vapour, an invisible gas. Warm air can hold much more moisture than cold air, which also means that warm, moist air has lots of energy stored in it to support the formation of strong storms. But how humid the air feels to us depends on how close the air is to saturation. That's the point where the air cannot hold any more moisture and the water vapour begins to condense into clouds, fog, dew, or frost. At the saturation point, the air is at the dew point temperature and the relative humidity is at 100%. Relative humidity is the amount of water vapour in the air at a given temperature expressed as a percentage of the maximum amount it can hold at that temperature. If the temperature of this air parcel is increased, the relative humidity will go down; if it is decreased, the relative humidity will rise.

> ***"Any fool can carry on but a wise man knows how to shorten sail in time."***
>
> – Joseph Conrad.

A high dew point means that the air doesn't need to be cooled very far before the water vapour in it condenses. A high relative humidity means the air temperature is close to the dew point and the air feels moist to us. As the relative humidity drops, the air feels drier to us. A summer afternoon with 50% relative humidity would feel dry and quite comfortable to us but would still contain much more total water than a moist winter day with fog.

As air cools, the water vapour contained in it has less room to exist as a gas. Once the temperature cools to the dew point (saturation), the gas condenses into either cloud droplets (clouds and fog) or liquid water (dew). The gas can also convert directly to ice as frost on objects or ice crystals in the air.

The cooling can be caused by many things. One way is by bringing mild, moist air into contact with the cold ground or water, causing it to cool in a shallow layer near the surface. This squeezes its moisture content out as dew and/or fog. On quiet nights, air will also cool simply by radiating the heat out to space. Another common process is the lifting of air by topography (orographic lift) or by convective air currents. In this case, the air cools by expansion because air pressure decreases with height. When it cools to the dew point, clouds form. Continued condensation forms so many of these particles that they begin to combine into larger droplets and eventually raindrops. If a shower is to happen, though, there must be so many large drops that they fall to earth and arrive without evaporating on the way down. A heavy summer downpour is the result of a simple process on a huge scale, as billions of rapidly condensing cloud particles join up to give us a break from the heat. The same moisture which we felt as "dry" air, can form heavy, wet downpours just by being lifted and cooled a few thousand metres inside a big cumulus cloud tower!

Moisture in the air is made visible by clouds. When the dew point is high (<15ºC) in summer, the cumulus clouds that form in the morning will be low in the sky and look soft and damp. With a lower dew point (<10ºC), clouds will form later and look more detailed and drier because they form at a greater altitude. As the day progresses, convective clouds evolve in appearance from soft and low to firm with higher bases. The daytime heating warms the atmosphere, raising the cloud base level. At the same time, clouds may grow taller because the warmer afternoon air can rise farther than the earlier, weaker updrafts. While all clouds help us to know what's coming in the weather (see pg. 25), convective clouds also tell us much about the air's moistness and movement near the ground.

Is the weather stable or unstable?

The difference between a sunny, stable day and a stormy one depends on the troposphere's temperature profile. The temperature normally decreases with height due to decreased pressure, but the presence of clouds, warmer or colder layers, and large-scale pressure systems also contribute. Since the air is colder higher up, you might think that all the warm air near the ground would automatically rise up into it – but there's another factor. Rising air also cools by expansion and will only rise as long as it remains warmer (lighter) than its surroundings.

The actual, measured temperature with height at any given time is called the environmental **lapse rate**. It averages 6.5ºC/km globally, but can vary greatly from place to place and day to day. As it increases, the air becomes more unstable. Stable weather will have a lower lapse rate or may even be warmer with height at some level. Any time there is a warm layer (warmer air above colder air) it is called an inversion. Stable weather with inversions inhibits vertical mixing of air, trapping haze and pollutants near the ground. By contrast, unstable weather often has cleaner skies and good visibility.

If the actual lapse rate is greater than the adiabatic lapse rate (see box), a rising air parcel will cool more slowly with height than the surrounding air. It remains slightly warmer than its surroundings and will continue rising. This is an unstable situation. To get air to rise to any significant height requires a tropospheric lapse rate that is steeper than average (becoming more rapidly colder with height), so that a rising air parcel will remain warmer than its surroundings for a long time. An air parcel will stop rising as soon as it cools to the same temperature as the surrounding air.

Adiabatic processes

Air cools by expansion on ascent and warms by compression on descent. This temperature change is not from an exchange of heat but due to pressure changes and is called adiabatic heating or cooling. There are two types – dry and wet. A dry adiabatic process applies to a rising or sinking parcel of dry (unsaturated) air. For dry air, the temperature changes by 9.8ºC/km. This is known as the dry adiabatic lapse rate. However, if the air parcel becomes saturated, its temperature changes more slowly with height because condensation releases heat (latent heat) to the ascending air parcel. This partially counteracts the cooling effect with height due to expansion. The net effect is a wet adiabatic lapse rate of 4.9ºC/km. Rising air cools at the dry lapse rate until the air becomes saturated (clouds form) after which it cools more slowly at the wet lapse rate. Descending air always warms at the dry lapse rate because cloudy, saturated air becomes unsaturated as soon as it warms up slightly.

In moist, unstable weather, rising air will condense easily and surge to great heights.

Condensation plays a very large role in how high a parcel of warm air will rise. Initially, the clear air cools at the usual rate as it rises. But as soon as a cloud forms in that rising air current, the latent heat released by the condensation slows down the cooling rate and makes the parcel more buoyant than it would have been if the cloud hadn't formed. Small clouds are also being cooled by evaporation as dry air mixes into the cloud from its edges – but once a cloud gets beyond a certain size, the extra heat helps it to grow much larger. After that, the only way it will stop rising is if the surrounding air becomes relatively warmer. This happens at the tropopause (where a thunderhead spreads out as an anvil cloud) but may also happen at a stable layer lower in the troposphere.

This means that moist air is potentially more unstable because it does not need to rise far to attain saturation, after which it is more likely to rise further. If there is some way to get moist air to rise in the first place – like strong daytime heating, topography, a front, etc. – then it will become unstable and form clouds and storms. A typical spring or summer day is stable at night, but becomes more and more unstable by late afternoon. Locally, the air may become more unstable as the moisture content increases or more stable as the surface layer cools over the cold water. Temperatures aloft can also change to alter the actual lapse rate, affecting the stability and expected weather.

As an example, let's say that the environmental lapse rate in the morning is 7.5ºC/km one day. The air near the ground will not rise on its own because as soon as it does, it would cool at 9.8ºC/km and would quickly become colder than its surroundings. But as the day progresses, the air is heated from below, increasing the environmental lapse rate near the ground. It can rise now and the warmer spots form updrafts. If these rise far enough to condense into clouds, then the wet lapse rate will kick in (see box, previous page). Now, this cloudy air cools at only 4.9ºC/km and stays warmer on ascent than its surroundings. It rises much farther,

In dry, stable weather, rising air takes longer to condense and is limited, resulting in small flat cumulus.

producing large clouds, until it reaches a stable layer at which the environmental lapse rate slows. Other factors like cooling by evaporation are involved too, but the principle underlying convective cloud formation is clear; it's hard to get them started but once they do, it becomes hard to stop them when it's unstable!

Most days in spring and summer have stable weather or become slightly more unstable during the daytime. Occasionally, temperatures aloft are colder than usual because a disturbance is passing through and the weather is unstable. Stable, fair weather days have vertical air currents during the day and produce only small clouds. Stability is often enhanced during clear nights because the air cools near the surface. That's why we see fewer clouds and showers at night than during the day. With unstable weather, air currents can rise many kilometres to form large clouds and storms. Some very strong storms even penetrate the top of the troposphere with powerful updrafts.

Air on the move

Air is very fluid and moves easily in response to pressure differences or obstructions in the flow. Horizontal air motion, especially near the ground, is mostly due to pressure differences from one area to another. Air moves toward lower pressure and away from higher pressure, just like water flowing down a slope. If the gradient is steep (large pressure difference) then the flow will be faster, creating windy weather.

Vertical air motion is not as straightforward. The most common way to move air up and down is with convective currents which form when the air locally is warmed or cooled and begins to

Most larger convective clouds do not form randomly but happen where the air is locally warmer, moister, or forced to rise in some way. Here, winds near the ground are converging along an axis, forcing the air to rise only there. This has produced a narrow line of rapidly rising cumulus towers.

rise or sink. Air will also rise or sink if it flows over a changing topography. As well, there are larger-scale currents exerting forces on each other throughout the atmosphere. Where they come together (converge) the air is "squeezed" and begins to "pile up" in one area. Similarly, diverging airstreams will create a region where the air spreads apart, leaving a void. In both cases, the air surplus or shortage can force air to flow up or down without the usual temperature influences. Variations in the flow pattern of the jet stream can induce pressure changes at the surface which then strengthen or weaken the weather systems already present.

Weather – The Elements in Action

Airmasses and fronts

If one day's weather is different from the next, it's usually because the airmass has changed. An airmass is characterized by nearly uniform properties of the air over a large region. Typical source regions would be the oceans, arctic, and sub-tropics. In spring and summer, the Great Lakes receive alternating spells of warm, humid air from the south and cooler, drier air from the Prairies. As one airmass moves forward against another, boundaries are created. When a boundary is a sharp dividing line or narrow transition zone, it is called a front. The type of front is determined by what the approaching airmass is like. So, a warm front is preceded by cool air and followed by warmer air, often with a change in moisture too. Cold fronts usher in colder, drier air. Fronts move with the pressure systems and occasionally lift off the ground or stop moving forward, becoming stationary for a short time.

> ***"Whether the weather be fine, whether the weather be not; whether the weather, whatever the weather, whether we like it or not."***
>
> – Traditional British School Rhyme.

Warm air is lighter than cold air and is easily displaced by it along a frontal boundary. Therefore, as warm fronts move in the warm air slides up over the existing colder air and as cold fronts move in the cold air plows into the warmer air, forcing it to rise. In either case, extensive clouds will form in the lifted warm air.

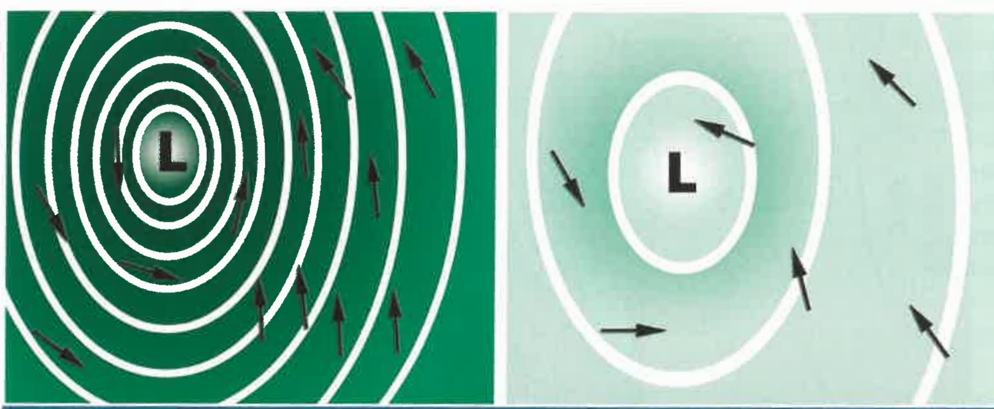
The contrasts between airmasses help to form and deepen lows. If the flow aloft is from the northwest, for instance, our weather is dominated by frequent spells of cool, dry weather as arctic airmasses spill in. In such a pattern, the milder phases contain airmasses from the Pacific which are relatively dry, so precipitation is light. But if the flow aloft comes up from the southwest, warm, moist airmasses from the Gulf of Mexico are drawn toward the Great Lakes, giving us mild, wet spells. Our weather is determined by the origin and frequency of the airmasses brought here by highs, lows and fronts.

Pressure and wind

Air pressure is the weight of all the air above us, measured in kiloPascals (kPa). The average pressure at sea level is 101.23kPa (1013.2 millibars), with summer averaging a little higher than winter. The air pressure is constantly rising or falling as spells of higher and lower pressure pass overhead. These weather systems contain large areas of rising (usually warmer, lighter) or sinking (usually colder, denser) air within them and are called “lows” and “highs”. For most of the year, pressure systems are strong and fast-moving, giving us changeable, windy weather. During the summer they slow down and are weaker, so we receive lighter winds and less day-to-day change in the weather.

Weather maps show us lines of constant pressure, or isobars. They are marked in millibars which equal the kPa values with the decimal moved over to the right. If you imagine these lines as similar to those on a topographic map, you can think of the pressure pattern as “hills” of high pressure and “valleys” of low pressure. The wind would then be like water flowing down a slope, from the higher points to the lower ones. The tighter the pressure gradient (closely packed isobars) the stronger the wind (see diagram, below).

When a difference in pressure exists from one area to another, the air will flow from higher to lower pressure, causing wind. Because the Earth rotates, the air doesn’t move directly from high to low pressure since the Coriolis force bends the flow to the right (in the Northern Hemisphere). The stronger the flow, the more it is bent, causing the air to spiral out of a high and into a low. This effect is most apparent when winds blow unimpeded over smooth terrain (such as a lake) where the stronger wind approaches being parallel to the isobars. However, over the land the wind is slowed down by friction with the rougher surface and crosses the isobars toward the low pressure. A practical example of this can be seen on a windy day, when the wind direction veers



The relationship between isobars, wind speed and wind direction. Wind strength is represented by green shading with darker being higher speeds. The strong low (left) has closely-packed isobars and the higher winds blow nearly parallel to them. By comparison, in a weaker pattern (right, the lighter winds cross the isobars at a greater angle).

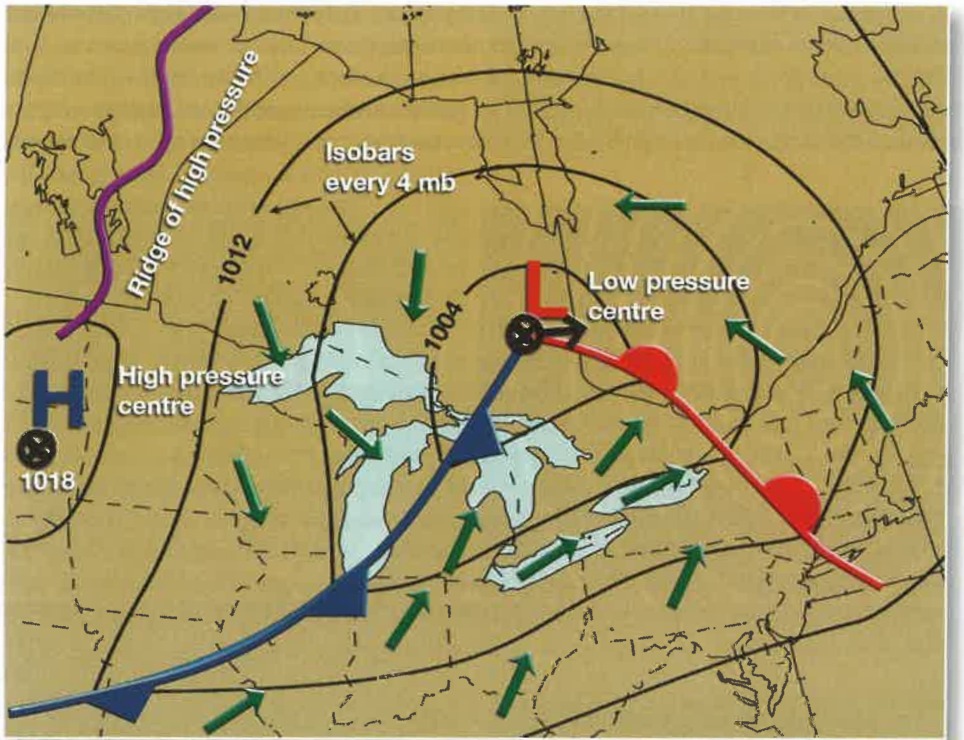
(clockwise change) over the lake relative to the land (see the example of coastal convergence on page 47).

As a general rule, the low pressure is to your left and the high to your right when the wind is at your back. This will be most accurate with strong winds as long as topography hasn't altered the wind direction locally. With light and variable winds, local effects such as uneven heating and topography will predominate over the influence of any nearby pressure systems in determining the wind direction.

A barometer is a simple but effective tool for keeping tabs on weather systems. It's fun to see the evidence of an unusually intense high or low passing overhead. A changing barometer is a sure sign of changes to come outside, too. The actual pressure from day to day is less important than the rate of change you see. Sharp changes indicate tight pressure gradients and well-developed systems which are likely to have a greater impact on your weather.

Weather systems

A high pressure area, or high (H), is a region of slowly sinking air and generally fair weather. It is often cold and dry, but summer highs can become hot because of the long, sunny days. Highs in winter can be strong (103kPa or more) with tight gradients and strong winds, but most highs



Depiction of the basic elements of weather systems.

have lighter winds near them. Highs approaching the Great Lakes are often weakening slowly (falling pressure) but occasionally a high will strengthen ("build") as it moves toward southern Quebec. An elongated area of high pressure is called a ridge. During a spell of unsettled weather, successive lows may be separated by only narrow, weak ridges which offer little relief from endless cloudy days.

A low pressure centre, or low (L) , is a region of mild, moist rising air and unsettled weather with clouds and precipitation. Lows can be small or large, weak or strong, and are usually intensifying or weakening ("filling") at any given time. In the Great Lakes, lows can intensify as they approach and pass, giving us more weather than we may have expected from the previous day's forecast. An elongated area of lower pressure is called a trough. Troughs are generally weaker and smaller in scale than most lows and are often accompanied by a narrow wind shift line. Deep lows (99kPa or less) from the southwest track regularly across the centre of the Great Lakes (see Intense lows, pg. 82), giving us stormy weather. In the summer months, however, the lows are not very prominent and most of them pass well to the north of the region.

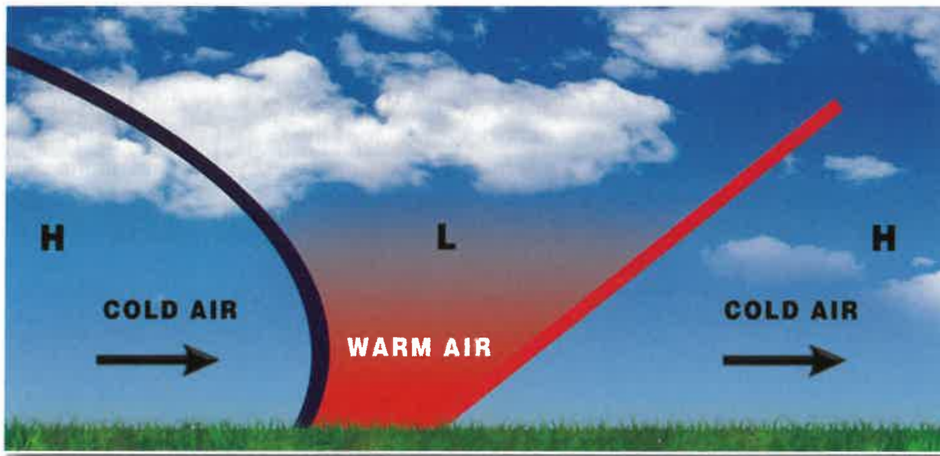
The Great Lakes Basin is a fairly active region for low pressure systems, which bring us most of our weather. Many spring and fall lows coming from the southwest deepen rapidly and pass over the lakes, bringing a great mix of weather and wind conditions. Another track from the Prairies carries weaker lows and frequent cold fronts across the Great Lakes area in summer and fall. The predominant track for highs is from the west-northwest year-round. In the winter, pressure systems are stronger due to the greater contrast between warm and cold airmasses and we experience more cloudiness, higher average winds, and a rapid turnover of weather conditions. By contrast, everything slows down in the summer, high pressure dominates, and winds are lighter in the weaker pressure gradient.

Action at the front

A well-developed low usually has both a warm front and cold front extending from its centre. As the low nears, the warm front brings in clouds and warmer air. As the low passes, the cold front replaces the warm, moist air with cooler, drier air again. You could imagine the low centre as "riding a wave" because the two fronts come together in that shape on a weather map. This is logical too, since the low's energy originates in the wedge of warm air between the fronts (the "warm sector") that is being slowly lifted to create the lower pressure. Initially, clouds form along each front because the lighter, warmer air is easily lifted above the cooler air. As the low deepens, an expansive cloud deck spreads out at mid-levels around and above the low centre. In the latter stages of a low's evolution, the fronts may separate away as the warm sector is pinched off the ground and occludes. With the heat source no longer present, the low slowly fills and falls apart.

A warm front marks the arrival of warm air. Because the warmer air lifts easily as it moves toward the cooler air, it slides up and over the cool air at the surface to form a broad band of clouds and steady precipitation. The winds aloft blow the highest clouds farther forward so they arrive first, followed by a steady thickening and lowering of high and middle cloud layers. Once clouds begin to thicken (become darker and/or denser), we have from 6-12 hours lead time before the weather turns foul. This is typical of summer but lead times will be longer in winter.

Precipitation begins as light rain or showers but often progresses to heavier showers or thunderstorms before ending with drizzle, fog, or low clouds. (See diagram, top pg 33). Winds are usually from the east or southeast and light to moderate; they become lighter near the front, then shift and increase to south or southwest as temperatures rise. Pressure falls with the front's approach, then becomes steady or rises slightly as it passes by. The weather can vary from widespread rain to only a few showers, or just cloudiness with a warm front. It all depends on the degree of overrunning of the warm air, the atmosphere's stability, and how moist the warm sector is. During the warmest months, many warm fronts are part of lows passing well to the north of the region and their arrival brings only middle and low cloud layers plus a few isolated thunderstorms.



Vertical cross-section of the atmosphere showing a warm and cold front (exaggerated in height). The cold air ahead of the warm front retreats but also resists the advance of the warm air. At the cold front, cold air pushes forward more rapidly, eventually overtaking the warm front and occluding the warm sector.

A cold front brings in an abrupt change to colder conditions and often breezy, changeable skies. The advancing cold air pushes into the warm, moist airmass forming a narrow bank of showers and storms along and just ahead of the front. The sudden arrival of a cold front gives us very little time to prepare for what's coming so it is especially important to look at the forecast and the sky. When a broad band of showers and cloudiness is present, we may have several hours warning, but sometimes the only sign is the building convective clouds and overspreading anvils from thunderstorms (see page 71).

A period of rain or moderate showers accompanies some cold fronts but most will have scattered thunderstorms ahead of the wind shift and colder air. A few isolated storms may pop up in the warm air, followed by a more extensive line of storms. Winds ahead of the cold front are usually south to southwest and gusty during the day, becoming west to northwest after the front passes. Pressure will fall slowly beforehand but rise sharply after the winds shift. Cold fronts, too, can vary greatly; from wet and cloudy to dry with only cumulus around. The sharp changes and generally windier conditions with cold fronts can create unpredictable wave conditions and difficult navigation.

Ragged stratocumulus cloud with towering cumulus embedded providing showers in distance.

Weather and your safety

Just as lows, fronts, etc. determine the direction and strength of their associated winds, upcoming weather events can be monitored and interpreted by watching for changing wind and sky conditions when you head out onto the water. Timing on an approaching weather situation (see chart, page 29) may make the difference between a safe, pleasurable outing and one that catches you unprepared.

As a boater you don't want the weather to change suddenly, surprise you, or become too windy or stormy while you're out on the water. All of these changes are part of a bigger picture and the more familiar you are with its pattern and characteristics, the lower your risk will be. The Great Lakes, being large, are already a challenge – even in ordinary fair weather. When strong winds or active weather are present, the waters can quickly become a very unwelcome place to be.

Quick Tips

First, get used to looking over the forecast map, which is you blueprint of upcoming weather changes. Get a feel for where and how fast lows and fronts move in each 12-hour period. Sense the wind and imagine the position of the lows and highs around your region. Next, become familiar with how clouds look, move and change over time. Relate cloud progressions to approaching weather systems and watch especially for the sudden changes brought by thunderstorms. Finally, use the general wind, temperature, and moisture conditions to anticipate trouble spots away from shore. Local areas of fog, high waves, and still winds are often the logical outcome of the present weather, magnified or modified out over the open water.

Clouds – Weather Made Visible

There is a never-ending parade of highs, lows, and fronts encircling the globe at our latitude. The sinking air near a high pressure centre or ridge results in an absence of precipitation and only scattered low clouds. This is because sinking air warms up as it descends toward the surface. This causes existing clouds to evaporate and suppresses new cloud formation. By contrast, near a low pressure system or trough, rising air condenses into extensive cloud layers and precipitation.

Most of the clouds we can observe are carried along by the westerlies and show us where the weather systems are coming from. The highest clouds arrive first, followed by thicker, lower layers. The lowest clouds, however, (stratus, stratocumulus, and most cumulus) move with the surface winds around highs and lows. This section will look more closely at clouds and what they signify.

Developing a weather eye

When you're surrounded by water, the sky takes on a new meaning by its dominant presence. Colours, shapes, and patterns parade majestically before your eyes in the quiet, mysterious process we call weather. The simple beauty and variety displayed in the sky is a pleasure in itself, but those clouds also carry the secrets of science with them.

Watching clouds move and change is the easiest way to keep tabs on the weather and avoid being surprised by it while on the water. Clouds not only mark the progress of large weather systems and fronts, but also indicate local variations in wind, temperature, and terrain. And during a typical summer afternoon, these local changes may be the only clues you are given to warn of a developing change in the weather.

The lower clouds (cumulus, stratocumulus, and stratus) will move with the flow near the surface (similar to observed wind reports). This is usually different from the direction of winds higher up, which carry weather systems from the westerly quadrant. All the other cloud types move with these winds aloft and, when watched carefully, will indicate where the next few hours' weather is coming from. In addition, the convection typical of unstable summer days will form large cumulus and cumulonimbus clouds which should be watched as they mature into thunderstorms. For these clouds, the progress in their changing size and structure (see Thunderstorms, page 66) is more important than their motion, especially when poor visibility restricts distant viewing.

Cloud cover will increase either by moving forward or by building where you are. Lows and fronts have sheets of cloud already with them which move forward, changing only slowly as they advance. At any particular location, these layers will progress from thin and high to thicker and lower with time. When cloud layers are absent, convective clouds often build during the day and fill the sky (mostly over land). In unstable weather, this progression also leads to cloudy skies and showers or storms, but this trend is more apparent as growth than as motion. The tops of thunderstorms blow forward with the westerlies aloft, giving us a hint of approaching distant storms. The lower parts of convective clouds change too rapidly and are too affected by local topography to be useful as good indicators of coming weather. Although the total cloudiness may increase greatly from morning to afternoon, it may yield no rain and usually dissipates in the evening. Thickening convective clouds leading to stormy weather will either be foreshadowed by thunderstorm characteristics (see When the Elements Rage, pg. 65) or arrive with a definite trough or cold front as indicated on the forecast map.

Relating sky change to the forecast map

The Environment Canada marine internet site contains analysis maps of winds and weather.

You can anticipate weather changes by taking this information and comparing it to the things you see happening outside. There are three general characteristics of weather systems that you can assess: speed, strength, and track. Speed will determine when you get the expected weather and clouds; strength will suggest how much and how long it will affect you, and; track will control the exact sequence of cloud change. If any of these factors vary from the estimates in the forecast map, a corresponding change will be evident in your local conditions. For example, the map might suggest strengthening winds and thickening clouds but you notice that neither is happening all day. It's likely that the low or front has slowed down or weakened, allowing fair weather to persist. In another case, the passage of a front or windshift may happen sooner or later than first thought and, again, will be apparent from what you see or don't see happening in the sky. Remember to keep checking the forecast as the day progresses.

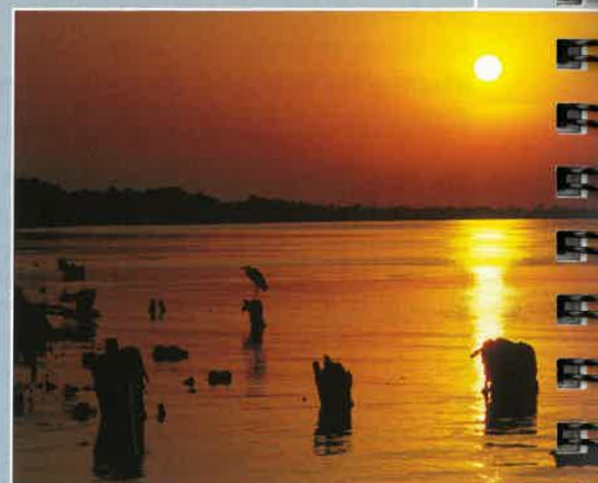
Well-developed lows and fronts have typical cloud, wind, and pressure patterns with them. As a warm front or low approaches, the higher clouds (cirrus, cirrostratus, altostratus) appear first and thicken, followed by altocumulus and later stratus or stratocumulus in the rain. If the low pressure centre passes well south of you, the high and middle clouds will thicken but may break up or clear again without bringing any precipitation. In summer, the systems are often weaker and are likely to contain more altocumulus and cumulus thickening to showers or thunderstorms. The weather associated with cold fronts is also more variable in the summer. Some fronts have wide bands of cloud and rain along them, while others are dry with only a few cumulus or isolated cumulonimbus. Sharp cold fronts can have strong lines of storms with them (squall lines) while others may be so diffuse that hazy skies, light winds, and developing cumulus and a few isolated storms are the main things you will encounter. (See the different fronts possible in the diagrams on page 33).

A typical boater's day for weather

One of the best days for activity on the water is a fair, quiet day in the weather. This happens regularly in the summer when a slow-moving high drifts just south of the region.

The day begins mild and a bit humid, but mostly clear, with light southwest winds and a few fog or mist patches. You may also see a few bits of cirrus or altocumulus cloud around. By mid-morning, a light onshore lake breeze begins and a few scraps of low cumulus appear farther inland. Over the next few hours, the cumulus clouds increase over the land but stay small. The air begins to feel drier as it warms and the lake breeze maintains a steady onshore wind, especially with water to your west to south. See if you can trace the shoreline in the sky by following the outline of the cumulus that line the lake breeze.

If the weather is stable, you won't see much change all afternoon. There may be a few larger clouds and darker bases mixed in with the rest of the cumulus, but nothing becomes very tall or large. If the weather is slightly unstable, a few of the larger clouds may grow into showers or an isolated thunderstorm over the land. Some of the cumulus will drift over the water and flatten, then evaporate slowly. Farther out over the water, it remains clear and winds are lighter than near shore.



In the evening, the trend reverses gradually. Low clouds evaporate before dusk, leaving only a few higher clouds at sunset. The sky is a bit hazy, and as the air cools it quickly feels moist again. Winds revert to a light southwest flow or become calm.

What could happen to change this scenario? A hot, humid, hazy day could trigger a late-afternoon storm over the land that sends a cool, gusty wind offshore. If afternoon winds pick up and remain southwest, a cold front may be nearing the region, bringing the chance for more storms and a band of thicker clouds with it. If a weak trough moves in, the daytime cumulus may grow large everywhere, filling the sky with dark bases. They may be joined by thickening mid-cloud layers culminating in showers or embedded storms. Whenever the entire sky clouds over and darkens in the summer, there are bound to be showers soon. You won't want to be stuck out on the water in that case.

The one other change which could have a big impact on your enjoyment is thick fog. Many fair, mild days can still be plagued by persistent mist and fog patches over cold water, which will limit your pleasure and your margin of safety.

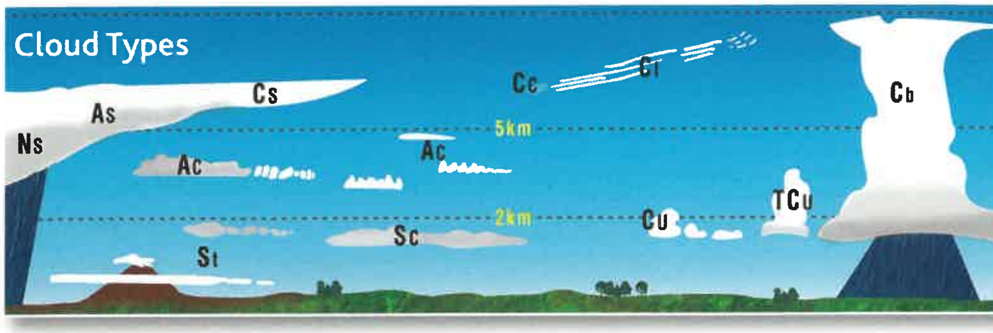
In a weak pattern, without any high or low pressure centres nearby, there are often smaller-scale disturbances (small troughs) embedded in the flow. These troughs have an associated increase in cloudiness and storms, followed by a light windshift, but they often do not appear on the map. Watching the general changes in cloudiness and wind direction will help you relate to the weather in your area that day.

How to read the signs

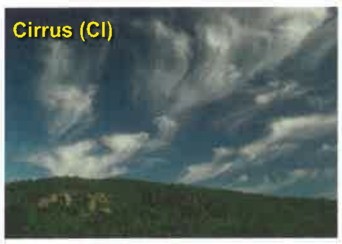
The table on page 29 relates basic weather situations to the changing sky, wind, and pressure conditions you experience. You can use it to compare the normally expected progressions for weather systems (as presented in the forecast map and marine synopsis) to the changes you observe, testing the forecast and fine-tuning your appreciation of what's to come.

The progression of weather elements has been broken down into two time periods. The "early" period refers to conditions from 6-12+ hours before the arrival of the event indicated on the map for your area. Following this, "later" is the 6-hour period just before the event. This is important since systems can change speed and the forecast map in only a projection of what the weather will be in the future. The table cannot cover all possibilities, but a keen weather eye will do much to help you adjust to unexpected changes. The four situations in the chart are numbered and keyed to the forecast map.

These rapidly building clouds will likely grow into storms in an hour or two.



This is a brief summary of the main cloud types referenced in the chart and photographs.
Note: Not shown below is the tenth common cloud type – Nimbostratus (Ns), a dense grey overcast from which precipitation is falling, often hidden by lower clouds.

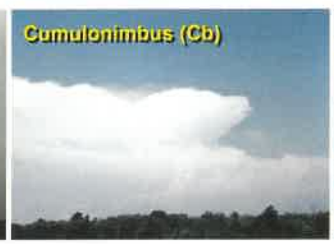


White, wispy or fibrous patches and strands

a smooth white veil, sometimes showing a halo

fine white elements in patches, "mackerel sky"

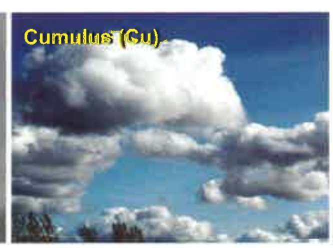
a uniform light grey sheet, faintly textured, showing the sun as a blurry dot



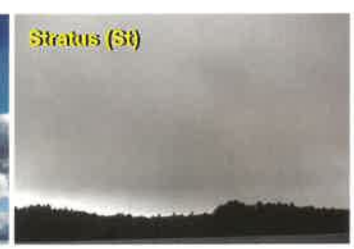
"thunderhead"' a large cloud mass with a dark base and heavy rain, and bright top; top can be rounded or fibrous but is often obscured by lower clouds

patches or sheets of crumbly or lumpy small elements; occurs in many different forms and situations

low sheet, patches, or rolls of soft, lumpy elements, common in cool spells and fall-winter



Small, puffy white clouds formed by rising warm air currents, with bubbling tops and dark, flat bases when larger

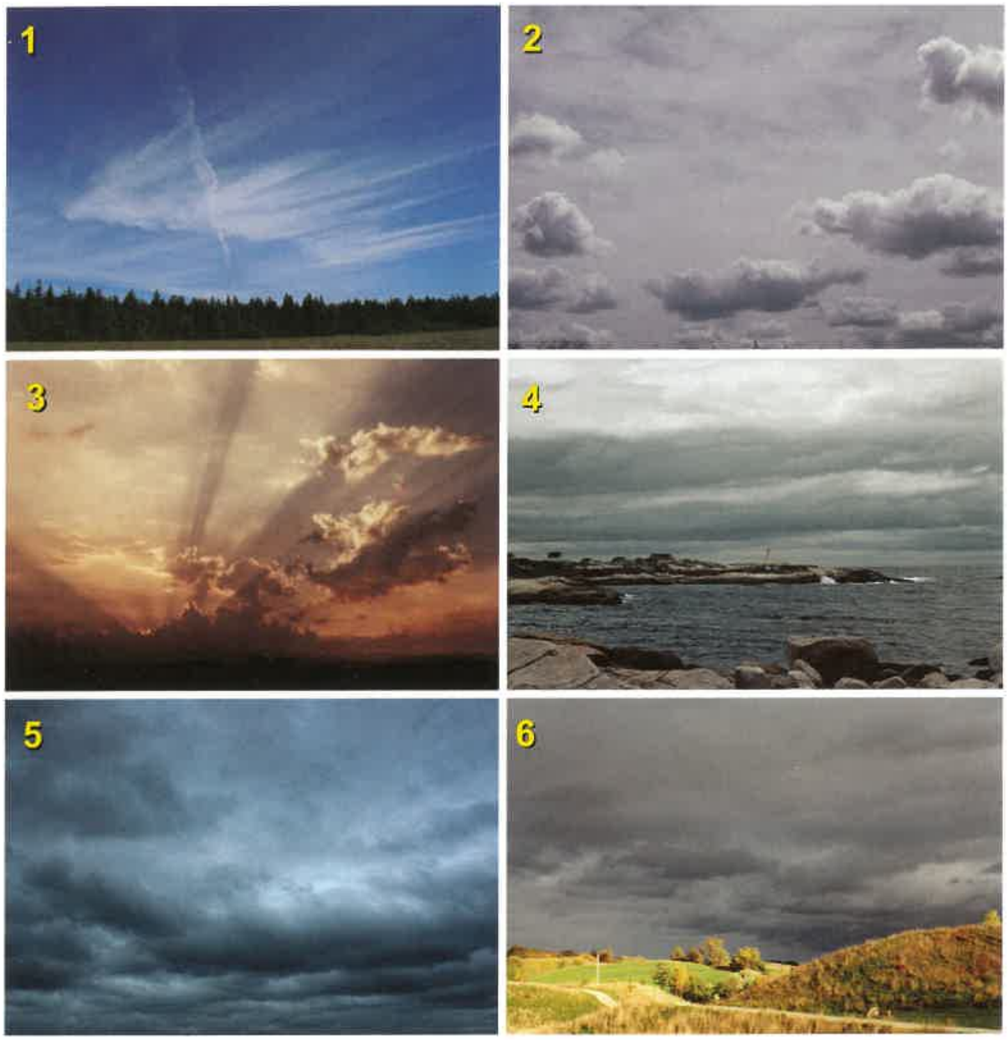


soft grey/white layer or patches with no detail just above the ground (fog is stratus resting on the ground)

	1 WARM FRONT or LOW pressure approaching	2 COLD FRONT approaching
Weather	Fair early, but steadily increasing clouds, becoming overcast. With the warm front, a period of rain or thundershowers then misty with low clouds near front. If low is passing near or to the south of you, steady light rain with mist and low clouds.	Fair early, with scattered cloud. In spring and fall, cloudy along the cold front with showers, a few thunderstorms, and possible squalls. In summer, increasing daytime cloud with showers along and ahead of the cold front; storms may form suddenly.
Sky & Clouds	EARLY: Fair, dry, with patches or thin layers of mid- and/or high cloud (Ac and/or Ci/Cs) LATER: With a strong low passing near or to your south, layers thicken to As overcast, then rain. With a weak low, a low passing well to your north, or weak warm front, usually broken layers of Ac thickening to overcast, then showers. Embedded thundershowers during late spring and summer. As warm front/low nears, higher cloud layers are often replaced by low clouds (Sc and St) and mist in or near the rain, followed by fog and drizzle until the front passes and wind shifts. **TIPS** • Large or deep lows will have bigger cloud systems that (1) take longer to thicken, and (2) lead to longer, more general rains. • Watch if the clouds follow a steady progression from Ci—Cs—As and/or Ac, then lower overcast; if breaks remain, system may be weakening, slowing down, or missing you. • Look at how fast the higher clouds move and where they are coming from to assess the system's progress and your likely weather over the next few hours.	EARLY: Fair, with scattered Cu and Ac patches. In summer, an isolated Cb may occur in the humid warm sector or in unstable air. LATER: With an organized low, fair until cold front arrives then a band of thick Ac and Sc with embedded showers and a few Cb's. If it is a cold front only (common in summer), there is some Ac but mostly scattered Cu growing larger near the front, with Cb's, especially afternoon and evening. Rapid clearing or Sc behind the cold front and windshift. **TIPS** • A line of thunderstorms (squall line) can form well ahead of the cold front and be followed by a windshift and clearing; the actual front will arrive hours later (sometimes with more storms). • In mid-summer, always watch for isolated Cb development, even if the sky is fair. • If a sheet of As invades the sky and darkens rapidly, a strong thunderstorm/squall line will arrive in 1/2-2hrs. • Slow-moving or stalled cold fronts can produce widespread, persistent thundershowers and mist.
Wind	EARLY: Winds light NE-SE, becoming light to moderate from the E quadrant as clouds thicken. LATER: If low is passing to your south, winds backing and moderate; if low is passing to your north, winds veering gradually to SE or S then SW after the warm front passes. **TIPS** • Watch out for gusty winds near thunderstorms. • Winds may be light along warm front in summer. • If lows moving from the SW (especially in spring and late fall) deepen rapidly, the warm front passage will be accompanied by a sudden wind increase from the SW quadrant, at 20-40 knots or higher.	EARLY: Breezy S-SW winds except light in a weaker mid-summer pattern. Winds gusty midday and near thunderstorms. LATER- Steady S-SW breeze until cold front arrives, then variable and gusty in showers, becoming W-NW or N after the front passes. **TIPS** • With a weak pressure pattern, the local lake breeze may change or override the general prevailing wind direction and speed. • Wind may temporarily change direction near or ahead of thunderstorms (often gusty W-NW).
Pressure	Falling until front passes, then steady or rising slightly. If low is passing to your south, falling until winds back to N then steady or rising slowly. **TIPS** • Rapid pressure fall will be accompanied or followed by moderate-strong winds. • Steady pressure suggests the low is weakening or slowing down; in that case, winds and clouds are likely to be delayed or less significant.	Pressure steady or falling slowly at first, falling as the front nears, and; then rising sharply after the cold front passes. **TIPS** • Pressure will fall rapidly just ahead of a strong squall line and rise rapidly after it. • Pressure may vary little in stagnant mid-summer pattern and fluctuate slightly near thunderstorms.

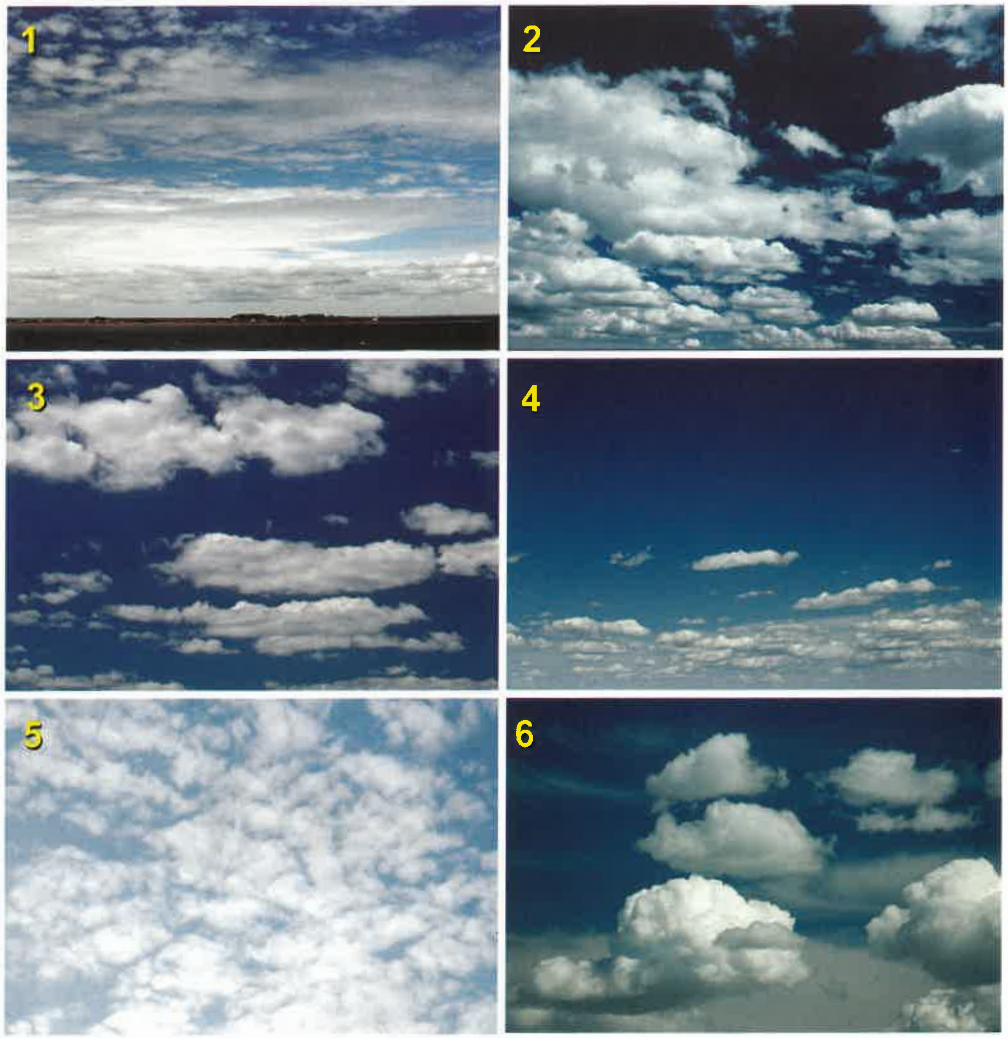
	3 HIGH pressure approaching or overhead	4 No distinct high or low nearby, or a weak pattern
Weather	If high centre is still well to your west, it will be cool and breezy with variable skies, daytime cloudiness, and a few light showers when unstable (especially late-summer/fall). Rest of time, clear to partly cloudy.	Generally fair; cloudiness will vary and be more extensive in the afternoon over land. Weak disturbances in the flow (troughs) can bring a few showers but this will not last long. In a stagnant, humid pattern, isolated thunderstorms during the day over land.
Sky & Clouds	EARLY: With the high still to your west, broken Sc (stable) or Sc with a few larger Cu and showers (unstable), gradually decreasing to smaller Cu. LATER: Fair and dry with scattered daytime Cu and clear at night. A few isolated Ci or Ac patches can also be present, especially after the high centre passes you. **TIPS** • The cooling effect of the lakes in spring-summer will often keep skies totally clear over water while many Cu are present just inland. • In mid-summer, air may remain warm and moist (more unstable) allowing isolated daytime Cb's to form over land. • During humid weather or with a large, slow-moving high, haze and early-morning fog patches will reduce visibility. Local fog and St will disperse a few hours after sunrise. • A cold spell in fall will contain extensive low cloud and scattered showers where the flow is to the lee of the lakes. • Cloud from the next low or front can sometimes arrive while pressure shows that the high is still overhead.	Steady-state pattern with little change over time, except generally fair to clear at night but scattered to broken daytime Cu and Sc. When unstable or if a weak trough is passing, brief period of Ac and Sc layers with a few larger Cu or Cb's embedded. A stagnant mid-summer pattern leads to heat waves and isolated Cb's. In spring or fall, variable cloudiness but dry is most common. **TIPS** • If a pressure gradient exists, clouds will depend either on daytime heating or on the presence of weak disturbances in the flow. • If the pressure gradient is slack, morning St and fog patches will give way to daytime Cu and isolated Cb's, usually only over land.
Wind	EARLY: Breezy from the NW quadrant until the high arrives; light and variable with the high overhead, often backing from NW to SW or S. Gusty winds during the daytime, light at night. LATER: If the high has a discrete centre, wind backing to SW-S and increasing (with centre passing to your south) or backing from N to E-SE (with centre passing to your north). If the high is weak or elongated as a north-south ridge, winds light N becoming calm, then S later. **TIPS** • In high pressure, winds are strongly influenced by the lake breeze, local topography, and shoreline shape. • Don't let an early-morning calm fool you; afternoon winds are often gusty!	In a stagnant, mid-summer pattern with a slack pressure gradient, winds are calm at night and light during the day. Speed and direction are largely determined by local conditions and lake-effects. With a stronger gradient, winds are light to moderate day and night. Direction depends on the proximity of the nearest high or low. Three common examples are: (1) high to your south with lows and fronts passing to your north, winds breezy SW; (2) high to your west or southwest, deep low to the northeast, flow moderate from W-NW; (3) high to your east with low over the midwest and steady S-SE flow over the Great Lakes. In these cases it is assumed that the pattern is stationary or very slow to change.
Pressure	Rising, then becoming steady. Falling slowly after high centre or ridge passes. **TIPS** • As pressure levels off, expect winds to become light and variable. • If a high continues to strengthen after passing your area, the pressure will keep rising slowly even though winds have already backed; the weather will remain fair.	Changes in pressure will be very gradual, if any, with slight fluctuations if weak troughs are present in the flow. The pressure tendency will not be useful in this case in determining future weather conditions.

Clouds Associated with Low Pressure

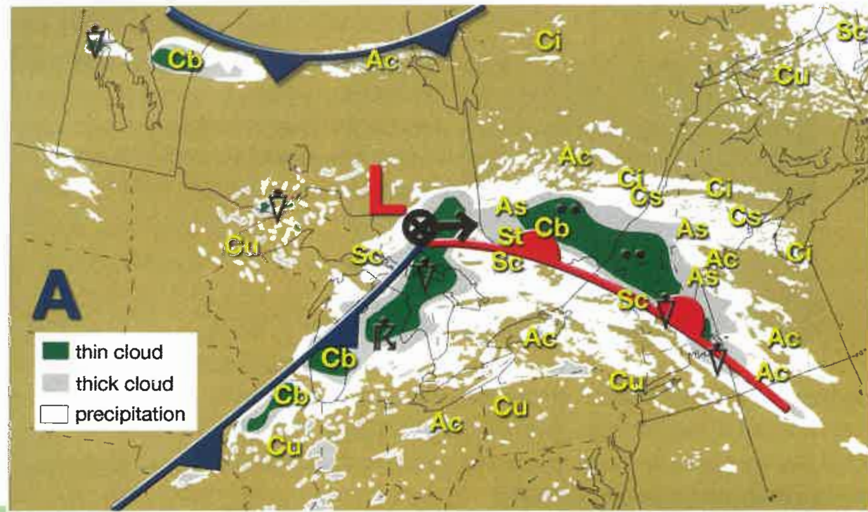


The earliest sign of a low or warm front is a cirrus sheet **1** overspreading the sky. It is often seen converging to the horizon (emanating from the direction of the approaching low) and will become cirrostratus later, then thicken and lower to a leaden-grey altostratus sheet **2**. If the system is weakening **3** or passing to your south, clouds will first increase then stay the same or thin out again. Unlike **2**, the altostratus sheet in **3** (with Ac below) has breaks right to the horizon. Some lows and many summer warm fronts have thickening altocumulus rather than cirrus. These can move in abruptly, going from clear to overcast in a few hours **4**, or may take many hours to thicken up. If a warm or cold front has a large band of rain with it, the higher overcast will progress to a low altocumulus overcast **5** which shows a lumpy texture and blotchy appearance. Showers will then begin soon and progress to heavier rain later. On days with convection, clouds of all types and at various levels can be present **6**. These mixed skies take a little more work to interpret since some parts of the sky may be harmless leftovers while other parts can harbour newly-formed showers or storms.

Clouds Associated with High Pressure

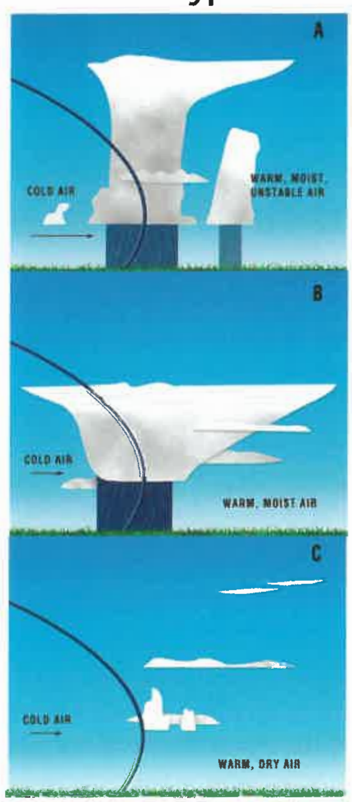


As a low or cold front moves out, the earliest signs of high pressure are apparent in the breaking up of clouds, drying out of the airmass, and lightening winds. In **1**, a northwest flow maintains broken stratocumulus or altocumulus patches and a few cumulus but no showers. If the air is cool and still slightly unstable, fair days will begin clear but quickly become mostly cloudy midday **2** as cumulus grow in the sunshine. A few light afternoon showers may occur but it will clear around sunset. As the high centre nears, the daytime cumulus will flatten and leave only a few altocumulus patches **3** in the late afternoon, which will soon evaporate. It's perfect weather for a day on the lake when the high is overhead. There may be a few cumulus or isolated cirrus patches in this dry, clean airmass **4** and lake breezes will keep the heat down. Patches or sheets of altocumulus can arrive under high pressure **5** but they usually remain isolated or are seen to "crumble" and evaporate. Fair weather will continue, but there may be more cloud layers farther north or later that day. Sometimes, even with high pressure, an isolated cumulonimbus cloud (thunderstorm) will pop up inland **6**. This is most likely with humid weather or with a passing weak trough which isn't obvious from other indicators.



Locations of various cloud types associated with weather systems (idealized). Clouds are indicated by their abbreviations (see page 28).

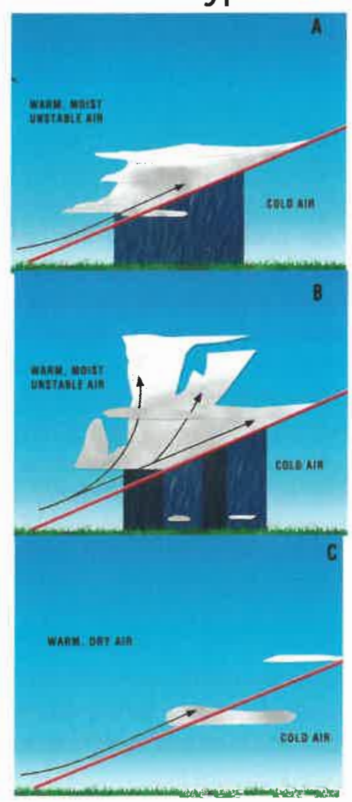
Cold Front Types



◀ **A)** A typical summer cold front will have scattered showers and thunderstorms with it. **B)** If the front is slow moving in summer or part of an organized low in spring-fall, it will have a wider band of showers or rain with it. **C)** Sometimes the air is too dry and only scattered clouds will be present.

▶ **A)** A typical warm front year-round will have a broad band of cloud and precipitation with it. **B)** In spring-summer, some warm fronts will have bands of showers with embedded thunderstorms, or have only a few storms with them. **C)** Some dry warm fronts have only high cloud patches or layers with them.

Warm Front Types



Weather lore

Long before we had our daily forecast – before the science of meteorology, satellites and computers – people were successfully predicting the weather by simply watching the clouds. A combination of pattern recognition, association, sensitivity to their environment, and common sense gave our ancestors all they needed to know about the weather to come. Today's portent became tomorrow's outcome, just as surely as the wind carves the wave.

You can sharpen your own skills by watching the clouds and learning what they bring. The examples below are just a few of the many words of weather wisdom written over the ages. Most are true most of the time, but there are always exceptions because each saying was based on a particular region and its prevalent cloud feature. Variations in the direction of motion, time of year, local effects, or just plain unpredictability of some weather situations can change the expected outcome, rendering some lore unreliable at times. But even then, exceptions can tell us just as much about the weather by drawing our attention to what didn't happen and why that might be so. Check out how reliable these are for you, and then create your own favourites from the clouds you see in your area.

"Hen's scarfs and mare's tails make lofty ships carry low sails."

"Trace in the sky the painter's brush, then winds around you soon will rush."

The sun is shining, the winds are light, the pressure's high – not much going on in the weather, you might think. It is true that most of what happens right under a high is not particularly noteworthy, but there may be a few scratches and scrawls up there worth reading. The very earliest signs of the next low or warm front often arrive during high pressure as thin tufts and streaks of cirrus clouds. These frozen wisps are but the thinnest slivers of moisture carried far ahead of the thicker, lower cloud layers that will inevitably invade the area. The next day, the winds will freshen and the signs at hand will no longer be as subtle as those first few innocent tails of prophecy.

"Rain long foretold, long last; short notice, soon past."

This is a simple yet profound verse that talks about the scale of weather, both in time and distance. Large low pressure systems create extensive areas of cloud and rain. Strong winds aloft carry the highest parts of the cloud area far forward of the low centre and most of the rain. This cloud is constantly being added to near the low centre and

expands away from it, usually to the north and east. The winds aloft "stretch" this cloud shield forward so that a thin layer of high cloud arrives at a location up to 24 hours before the rain does. Hence, the rain can be "long foretold". While it takes a full day to thicken the cloud up, once rains begin they also persist for an extended period ("long last") as the main part of the low makes its way through. The scale of a weather system is, therefore, matched by its lead time.

On the other hand, convective showers, which are small in size and extent, give us little forewarning because they are constantly forming and evaporating. These clouds also move relatively slowly. The anvil clouds from storms rarely spread more than a few hours out ahead of the rain. The convective showers of summer, then, will leave just as quickly as they arrive.

"When the sun is in his house, it will rain soon."

photo credit: Jonathan Martin DeMoor

This saying, like the previous one, is a sure bet of coming rain. It takes a well-developed low to form the large, uniform sheets of high cloud which progress smoothly from thin to thicker. That's what is required to form a halo in cirrocumulus. The halo, though only present once in a while, does indicate a very uniform thickness of the ice crystal cloud layer. It is this homogeneous characteristic of cirrostratus that indicates it has been stretched out over a long distance and comes out of a large cloud system.

"When clouds appear like rocks and towers, the earth's refreshed by frequent showers."

On a day when there are a lot of tall cumulus sprouting everywhere, there are bound to be numerous showers too. The lively vertical motion allowing the rising towers to be taller than they are wide is a sure sign of very unstable air. Warm updrafts, once underway, are free to rise quickly and high into the sky. When the whole sky is full of such clouds by early afternoon, it means that showers are ready to break out everywhere. A little bit of heat was enough to get things going early and this will prevent larger, more isolated storms from happening, resulting in more frequent but smaller showers. The opposite occurs on a day with slightly unstable air; it takes all-day sunshine to heat the air enough to make it unstable and one or two bigger storms can then form later in the afternoon.

Growing cumulus which rise very quickly have “crunchy” tops – bright, hard crowns that look like rocks. The “hardness” is entirely due to the newness of the condensation at the top of the tower. New air emerges continuously at the top to form numerous small cloud particles that permit a hard-edged appearance there. As soon as the cloud top slows down, you will notice the detail getting softer and duller because evaporation dilutes the cloud edge. A sky full of rocks and towers tells us that all the clouds are growing vigorously and are not likely to stop until they have spilled their bounty.

“A dappled sky, like a painted woman, soon changes its face.”

“Mackerel sky, mackerel sky, never long wet and never long dry.”

The delicate, trickling texture of cirrocumulus clouds has long been compared with the scales on mackerel. Cirrocumulus is probably the rarest cloud type but it is also a very reliable predictor. It occurs almost exclusively with cirrus well ahead of a warm front. The way clouds thicken can vary with warm fronts and mare’s tails cirrus are only sometimes present – but if we see cirrocumulus patches, the weather is sure to change soon. Because these clouds are present ahead of the warm front (and not too far north of the low or too far south along the front), they suggest that the jet stream axis is overhead and the weather will continue to alternate between wet and dry spells for awhile.

“Red sky at night, sailors’ delight; red sky in the morning, sailors take warning.”

This could be the most famous rhyme ever associated with weather! It assumes a very basic fact about the clouds in the northern mid-latitudes – that they will move from west to east. If the sky turns red at sunrise, it means that clear sky to the east allows full sunlight to shine underneath the cloud layer now in the sky. These clouds are, therefore, moving in or thickening and may soon lead to rain. However, the opposite is true at sunset. The setting sun will redden the clouds present if the sky is clear on the eastern horizon, indicating clear weather to come the next day.

Fog – Clouding the Picture

> *"The fog was advancing as fast as the storm, dissolving rock, water and sky in its wake. Our fear riveted our attention to the task at hand."*
>
> – Barry and Joan McGuffin, canoeing on Lake Superior, from Kanawa, Fall, 1995.

Fog can pose a threat to boaters not only by decreasing visibilities to zero, but also by distorting sound. When you cannot rely on your senses it is easy to become disoriented. You may go far off course, and you may find yourself in shallow or treacherous waters that you would have avoided otherwise.

Most visibility problems are produced by fog, although haze, precipitation and pollution may also play a role. Under marine inversions the combination of high humidity and pollution may result in smog in harbours such as Toronto and Hamilton, but this phenomenon, however unpleasant, is unlikely to be hazardous.

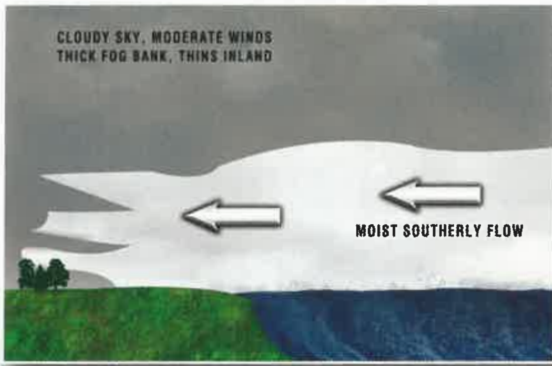
There is no sharp distinction between fog and other restrictions to visibility. With fog, visibilities generally range from 0-3 km; with mist or haze they range from 2-6 km. In a marine forecast, however, any visibility of less than 1 km is, for simplicity, called fog. When visibility is expected to be 1-5 km, mist is forecast. Otherwise, visibility is expected to be above 5 km.

Fog should always be treated with caution and respect. It may not be as dramatic a threat as stormy weather, but, nonetheless, can be a significant hazard to safe navigation. Boaters should be sure they are aware of the International Rules of the Road regarding fog.

During the recreational boating season (April to November), there are three types of fog you may encounter. As a boater, understanding the distinctions between these types may help you anticipate change in visibility and assess the differences in fog over water and fog over land. On the Great Lakes, advection or sea fog is the most significant.

Advection fog occurs when warm, moist air moves over colder water – water that is cold enough to bring the air temperature down to its dew point; the moisture contained in the air condenses into fog, much the same way as you can create a "fog" on a cold window by blowing on it with your warm breath, or see your breath on a cold day.

It follows, then, that you are most likely to encounter advection fog in areas where the water temperatures are cold and there is a warm, moist (generally southerly) airflow. When wind moves water along lake surfaces, cold waters may rise to the surface through a process called upwelling. Lake areas with very deep water, such as Lake Superior and northern Lake Huron, remain fairly cool because of continual upwelling in summer. This is borne out by the fact that heavy banks of fog persist on Lake Superior much later than they do on shallower waters such as Lake Erie, which is warm enough by July that little advection fog occurs.



Advection fog.

Advection fog is most common in the spring and summer and is thicker over water than over adjacent land masses. It tends to be persistent, lasting through the day over the water (although it may burn off by the shoreline). It can also persist with moderate or even strong winds, but will lift soon after the passage of a cold front or a change in the circulation. You should be alert to favoured areas where cold currents and/or upwelling of cold water create patches of fog. (see map, pg 40)

Radiation fog.

Another type of fog, more familiar on land, is **radiation fog.** Whereas advection fog occurs when there is warm, moist air over cooler water, radiation fog generally lifts in the morning after the sun has warmed the cool land surface. Unlike advection fog, radiation fog forms over land (more commonly inland), burns off quickly during the morning, and is only likely to occur on a clear, moist night with light winds. The earlier it forms, the longer it lasts. It may drift over water near shore when light offshore winds (land breezes) develop at night, but only the morning boater in harbours and river estuaries is likely to find it much of a problem. It rarely spreads far offshore and often lifts off the water surface to form a layer of low (stratus) clouds which quickly clear. When cloud cover moves in, it may take longer for radiation fog to burn off.

Frontal fog occurs with warm fronts and their associated moist airflow, and is more common in fall, winter and summer months. It can be thick over both land and water and will lift a few hours after the low pressure system or warm front has moved by.

Precipitation fog forms as the result of precipitation falling into moist air. Some of the rain evaporates as it falls, saturating the air around it and producing fog. This type of fog usually occurs on the cold air side of a warm front and is enhanced by a cold water or cold land surface. The fog area moves with the precipitation shield.

A winter phenomenon called steam fog or arctic sea smoke can occur from mid-December through to February. It forms when very cold arctic air moves over warmer water. The result looks like steam rising from the water and can extend several metres above the water surface. It is not particularly hazardous on the Great Lakes, but it may cause icing on decks and rails, which can make moving around on board quite difficult.

"Lights on, sound your horn, slow down, and post a lookout."

The usual advice for boaters about fog is "If you can't see, don't' go." Having said that, you may well find yourself blindfolded by fog, by choice or by chance. Upwelling and local changes in weather and water conditions can catch even experienced mariners by surprise, and boaters who depend on wind and manpower may find themselves stranded en route as fog envelops them far from their destination.

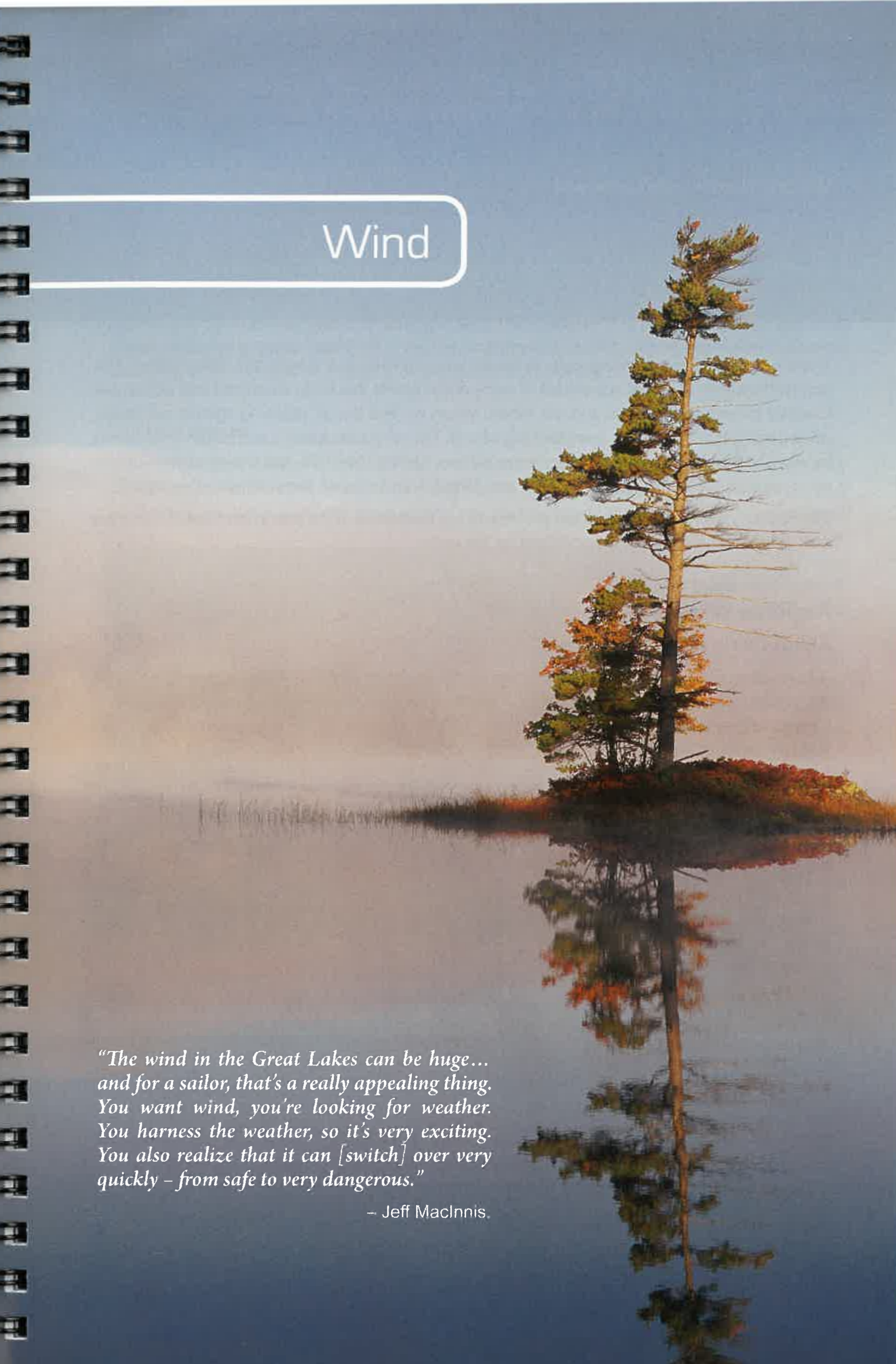
With very little visual warning of hazards, and some risk that sound clues are distorted, boaters must be on full alert but, at the same time, be prepared to have their senses play tricks on them. "When you are staring out into the shifting clouds of fog it is easy to see 'fog gremlins', vague shapes that can appear to be islands or lighthouses or ships." (Richard Spilman, in Sea Kayaker, Fall, 1992)

Key points to remember when navigating in fog are:

1. If you can safely get back to home port, do so. (If you are in port, stay there!)
2. Slow down. Give yourself and other boaters time to know where you are.
3. Put your lights on. Small craft equipped with radar reflectors should use them if there is any likelihood of shipping traffic.
4. Use a horn or whistle to signal your presence to others but don't distract yourself with music and conversation. Stay alert to sound and other sense clues from land, buoys, or other boats.
5. Put your PFDs on, if you aren't already wearing them.
6. Avoid getting run over. Check on you VHF for other traffic, and give out your location.
7. Use all available tools: a GPS can be a lifesaver, if you have one. Otherwise, keep your eye on your compass and charts, and keep track of time.

July average water temperatures. Fog will be more frequent and persistent in the colder areas, especially during warm, humid weather.

Wind



"The wind in the Great Lakes can be huge... and for a sailor, that's a really appealing thing. You want wind, you're looking for weather. You harness the weather, so it's very exciting. You also realize that it can [switch] over very quickly – from safe to very dangerous."

– Jeff MacInnis.

Watch those wind arrows!

Throughout this book, variations in the thickness of wind arrows indicate variations in wind speed. (The thicker the wind arrow, the higher the wind speed). In some of the diagrams of nearshore wind effects, these variations are quite subtle. Make sure you look for them!

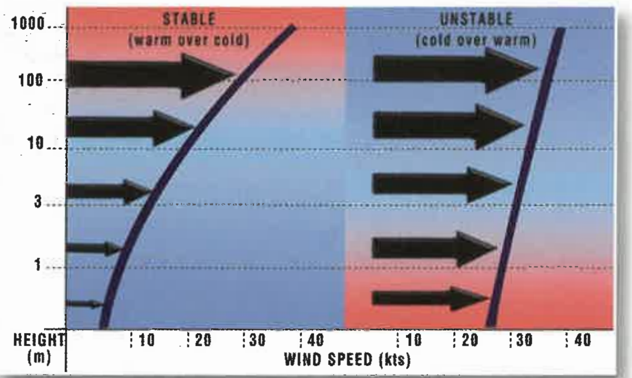
There's nothing like a roaring gale to rouse your senses and inspire the imagination! The atmosphere is an ocean of activity, full of swirls and currents that bring warm and cold airmasses together to form the weather and our winds. When we feel the air pressing against our faces, we are being touched by this planetary tug-of-war. The wind sails silently and invisibly by feeling its way through the forests and the narrow places, gliding over hills and waves-always on the go, a restless presence. It is fresh, new, and forceful, and shapes our waters and our spirits.

The causes of wind and large-scale processes are discussed in the previous chapter. Here, we look at local wind effects and conditions on the water.

Regional Wind Effects

Atmospheric stability and wind

A layer of warm air lying above cooler air at the surface creates a stable situation because the lighter, warmer air glides smoothly over the layer below it. The cooler surface layer is shielded from stronger winds aloft and remains relatively undisturbed. By contrast, if the surface layer is warmer than the air above it, the warmer air has a tendency to rise and be replaced by cooler downdrafts. This vertical exchange of air (mixing) brings the stronger winds aloft down to the surface where we experience gusty winds. In general, winds are stronger over water because friction slows down the flow over the land.



The variation of wind speed with height in stable and unstable conditions.

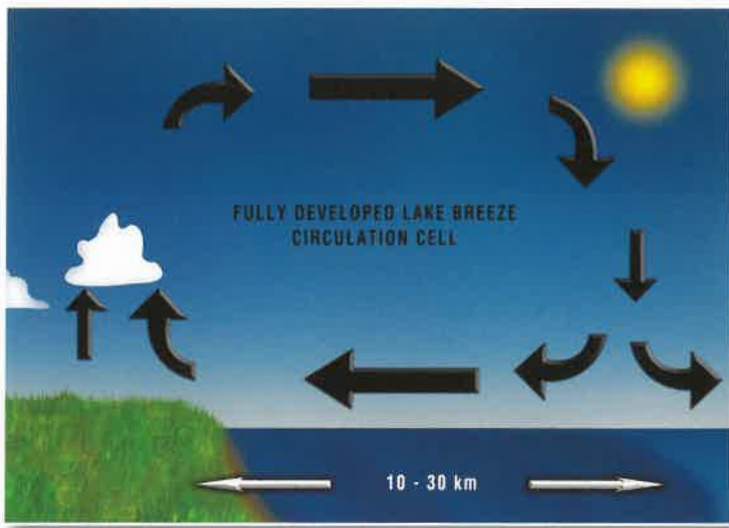
The most common example of a stable situation in summer is seen in daytime versus nighttime winds over land. During the day, the land heats up, rendering the air unstable, and gusty winds prevail. At night, the land cools, a stable layer forms and the winds are steady and lighter.

A special example of this process occurs over the Great Lakes on warm spring and summer days – the formation of a lake-cooled layer at the surface that is very stable and free of wind gustiness. This marine inversion is like a protective blanket on the water in which cool, calm conditions persist even though it may be windy farther up or over nearby land. Inversions can extend from a few metres to hundreds of metres. They form regularly during the boating season over the colder waters and during calm nights. They can cover large areas but are sometimes confined to protected, small patches surrounded by very different conditions. Inversions also often have persistent fog or mist with them.

The exact opposite occurs on cool days in late summer and fall when cool air from the northwest moves over the relatively warm waters and becomes unstable and prone to gusty conditions. The significance of these examples is the way stability or instability can weaken or enhance the prevailing wind to create challenging offshore conditions for the boater.

The lake breeze

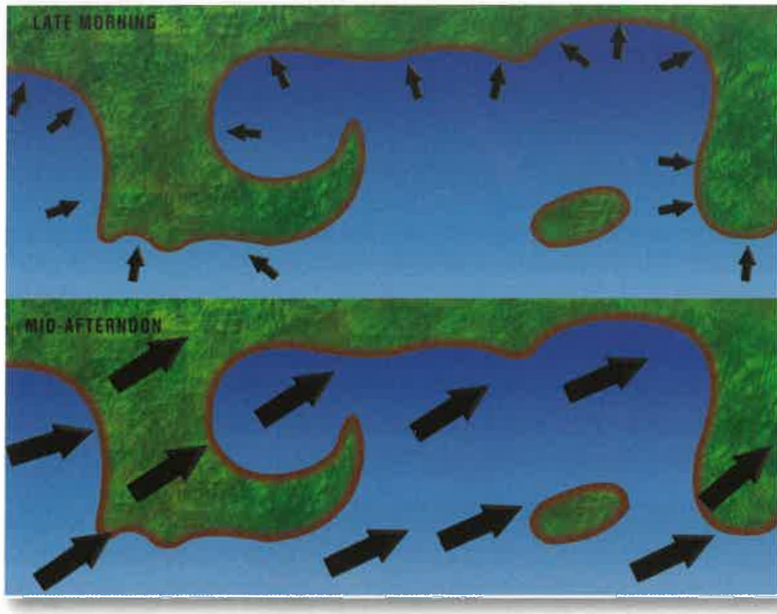
The sunny, warm days of spring and summer permit a sharp contrast to develop between air over the warm land and air over the cool lake. As the cooled lake air moves onshore to replace rising warm air currents inland, a circulation cell develops, and the lake breeze is established (see diagram). This circulation remains in place until around sunset, when the land cools down. Occasionally, a much weaker land breeze will form later in the night, blowing offshore until early morning.



The wind speed due to the lake breeze usually ranges from 5 to 10 kts but will either add to or subtract from that day's prevailing wind. The leading edge of the lake breeze is known as the lake-breeze front. Air has a net upward motion along this frontal zone and can cause to the development of cumulus clouds. Depending on the prevailing wind, the lake-breeze front can extend inland 100 km or more, or be stuck near the shoreline.

The classic lake breeze situation occurs under a clear sky and a light prevailing wind (< 10 kts). The lake breeze gradually penetrates inland nearly equally around the perimeter of the lake. The winds over the lake are divergent, with the strongest winds occurring near the shore but decreasing to calm near the middle of the lake (see diagram).

If the prevailing wind is moderate in strength (10-20 kts), the lake breeze circulation is typically shifted downwind somewhat, and the lake-breeze front on the downwind side of the circulation is typically not present. The area of calm winds moves toward the upwind side of the lake (see diagram).



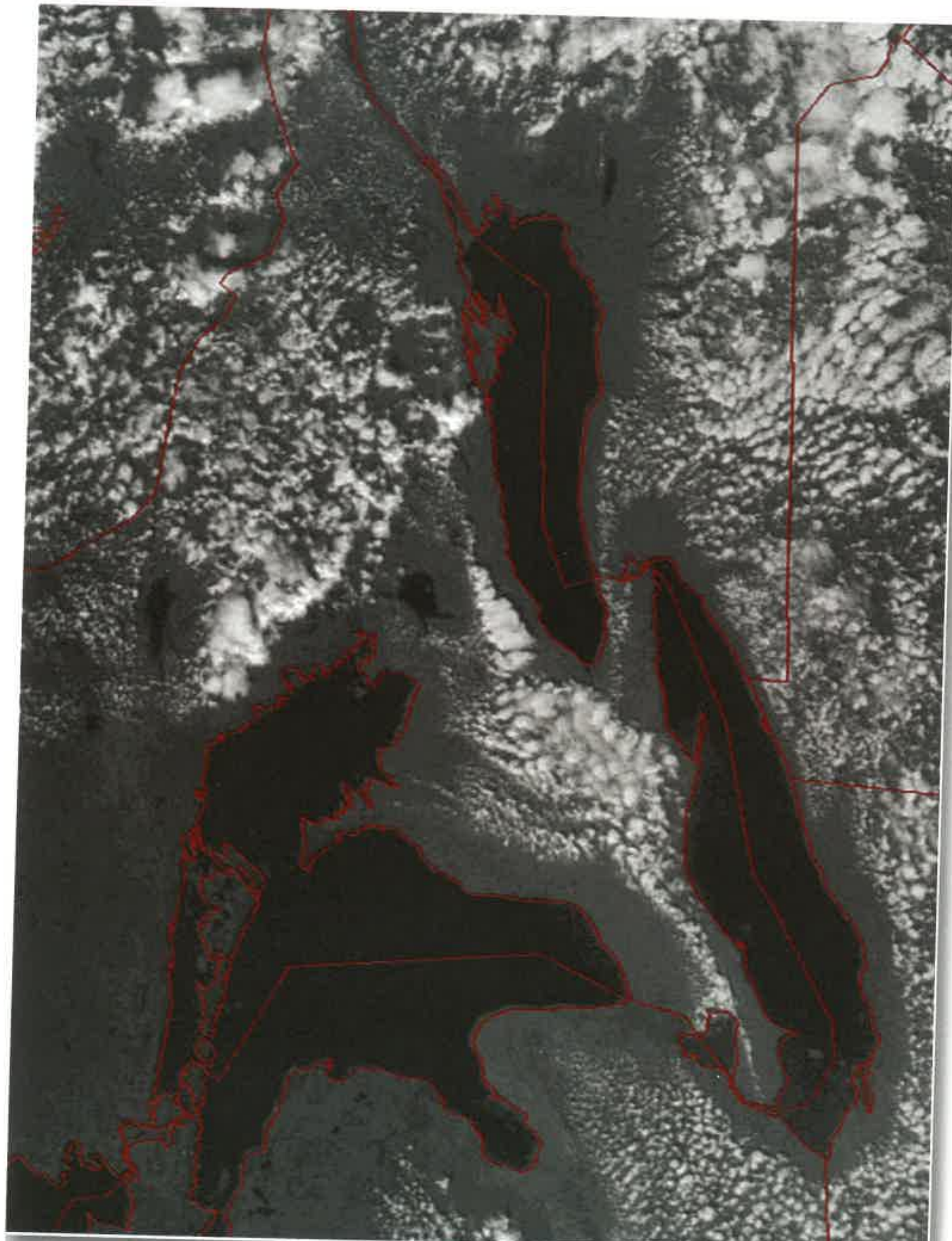
In the morning of a calm day, initially light local onshore winds are replaced by a more uniform flow from farther offshore as the lake breeze develops.

Finally, if the prevailing wind is strong (>20 knots), the lake-breeze circulation is usually shifted even farther downwind, and lake-breeze fronts are no longer present on the downwind or upwind sides of the circulation. The remaining lake-breeze front segments extend many kilometres inland in such situations. Winds over the lake are divergent, but there are no calm regions (see diagram).

If you are just offshore around mid-morning during a classic lake breeze situation, you will notice a light breeze begin to develop and move straight toward the land nearest you. Over time, the breeze will gradually increase in speed and become more uniformly onshore. By mid-afternoon, the speed reaches a maximum and the direction may veer by up to one compass point (i.e. from south to southwest). These conditions will remain until the lake breeze dies around sunset. A period of calm may then occur just offshore before the prevailing wind re-establishes itself. Of course, this is an idealized situation and is most likely during periods of stagnant weather or high pressure.

In the lake breeze situation with a strong prevailing wind, the change in winds over the lake may be imperceptible over the course of the day, and lake-breeze fronts may form not near the shore but well inland.

The lake breeze is a prominent warm-season feature of the Great Lakes, occurring somewhere around each lake on more than half of summer days. In fact, lake breezes have been known to occur daily for weeks at a time under the right weather conditions.



Satellite image of late summers day lake breeze effect convective cloud formations.

Nearshore Wind Effects

"Probably northeast to southwest winds, varying to the northward and westward and eastward and points between. High and low barometer swapping around from place to place, probable areas of rain, snow, hail and drought, proceeded or preceded by earthquakes with thunder and lightning."

– Mark Twain.

Most boating on the Great Lakes is done within a few kilometres of shore, and the characteristics of the shoreline (topography) and lake bottom can be important determinants of local wind and wave conditions. Furthermore, the lakes themselves present topographic influences on larger wind patterns that would not be found on the open seas.

To understand conditions in your area, Environment Canada forecasts are an excellent starting point. But they cannot give you the whole local picture. You must take into account the nearshore effects you are likely to encounter along your route. Are there islands, channels, cliffs or valleys which may create local variations on wind conditions? How does the shape and angle of the shoreline interact with forecast winds? How do lake breezes fit into the picture? And how do current weather conditions compare with forecast expectations?

What follows is an explanation of effects which you may encounter locally, accompanied by some Great Lakes examples of these effects. Learning the basic principles will help you understand some of the vagaries of the winds. Then, whenever you are preparing to set out on your boat, consider how these local effects might change or interact with forecast conditions.

Channelling/funnelling

When the shoreline is steep or rises gradually over many kilometres, it can cause changes to the speed and direction of the wind. Changes in wind direction – called channelling – can happen on both large and small scales. On the large scale (diagram right), channelling may redirect the wind down the length of lakes such as Erie and Ontario, or into large bays such as Georgian Bay. On a small scale (opposite page, left) channelling may curve wind along an object or cliff, as happens in Midland Channel, or on the north side of Lake Ontario (where high land bends southeast winds to run east, parallel to the coast).

Large-scale channelling and funnelling on Lake Erie. Note direction of winds along the lake axis and stronger winds at the east end.

If winds are forced through a narrow opening they also increase in speed (opposite page right). This effect, called funnelling, also occurs on both large and small scales. On a large scale, westerly winds speed up as they approach the east end of Lake Erie, where the lake

Channelling in the North Channel. Note redirection of winds along the east-west channel.

Funnelling of winds in Eastern Lake Ontario. Note the stronger winds in Adolphus Reach and Long Reach.

narrows. On a small scale, winds forced to blow through a narrow opening – such as between two islands, through an inlet or into a harbour from offshore – may increase to as much as double their original speed as they funnel through the opening. This happens frequently in Georgian Bay, where the many islands, inlets and channels can play havoc with the winds. It also occurs near the entrances to river valleys (for example, the St. Lawrence and Niagara rivers), or along steep shorelines such as Long Reach in eastern Lake Ontario.

Coastal convergence

If the wind is at your back and the shore is on your right, you may notice that winds are distinctly stronger (about 25%) in a band within a couple of kilometres offshore than they are over land or mid-lake. This effect (a good example is the eastern shoreline of Lake Huron), is called convergence (see diagram, right). It happens because friction causes surface winds over the land to back and converge with those over water, and the result is a "piling up of winds" near the shore. You may also notice that there is more cloud in an area where convergence is occurring. The "piling up" of winds creates an upward component to the flow of air, which may then condense into clouds.

Coastal convergence and divergence on southern Lake Huron. Note the stronger winds along the east shore and lighter winds along the west shore.

> ***"As I got into the funnel effect of the long reach between the island and the mainland, I noticed the waves were three-footers..."***
>
> – Dave Martin, in QAYAQ, Summer, 1996.

This piling up of the winds may also be accomplished by channelling (right). On Lake Ontario, southeast winds are channelled to easterly by the steady slope of the north shore. The resulting convergence or wind "pile up" produces stronger winds near the north shore than are experienced a mid-lake.

Convergence due to channelling along the north shore of Lake Ontario.

A less significant effect, divergence, occurs when the wind is at your back and the shore is on your left. In this case, there are lighter winds (or the opposite effect) just offshore than there are over land or mid-lake. This offshore zone of lighter winds is often overridden by a lake breeze during the day.

Corner effects

Obstacles such as steep islands and peninsulas can also make air flow around them. A steep peninsula will force air around it with a resulting increase in wind speed, just as winds increase in speed when they funnel through openings. But this corner effect results from a combination of friction (convergence) and funnelling effects on a small scale.

The wind flowing around a hilly island will speed up off both sides. However, the wind also backs (turns counter-clockwise) because of the friction over the island, and this, too, affects the wind speed. Looking downwind, the wind to the left of the island increases more than on the right side due to frictional convergence. The diagram right, illustrates how cornering affects wind speeds.

Corner effects around a steep island. Note that winds increase on both sides of the island, but are slightly stronger on the left than on the right. Also, note the gusty lee winds behind the island.

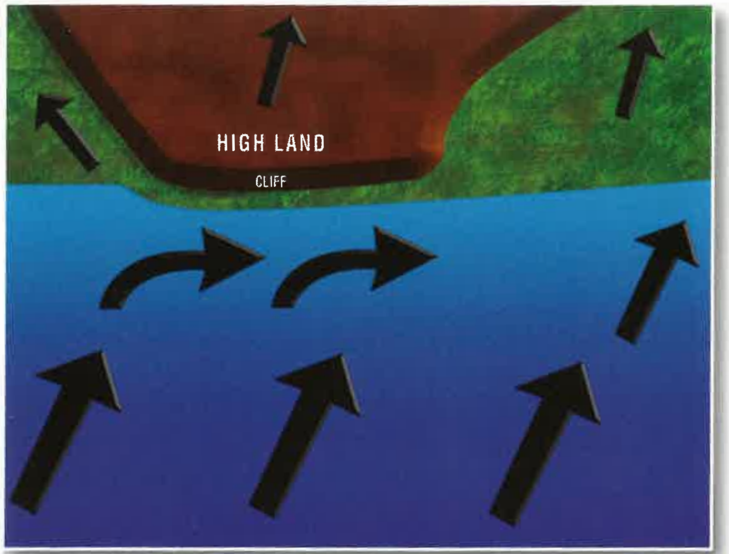
The persistence of stronger wind produced by corner effects depends on the size of the island or peninsula. They may persist for distances ranging from a few hundred metres (with a small island) up to tens of kilometres (Bruce Peninsula).

Rough terrain slows down air flow more than smoother land does, so a steep, rocky island or peninsula will create more noticeable corner effects than a smoother, lower one. With flatter obstacles there may still be some enhancement of wind speed due to corner effects, but it won't be dramatic.

You may also find there are turbulent gusty winds to the lee of the island or peninsula. This is due to lee (or cliff) effects.

Cliff effects/lee effects

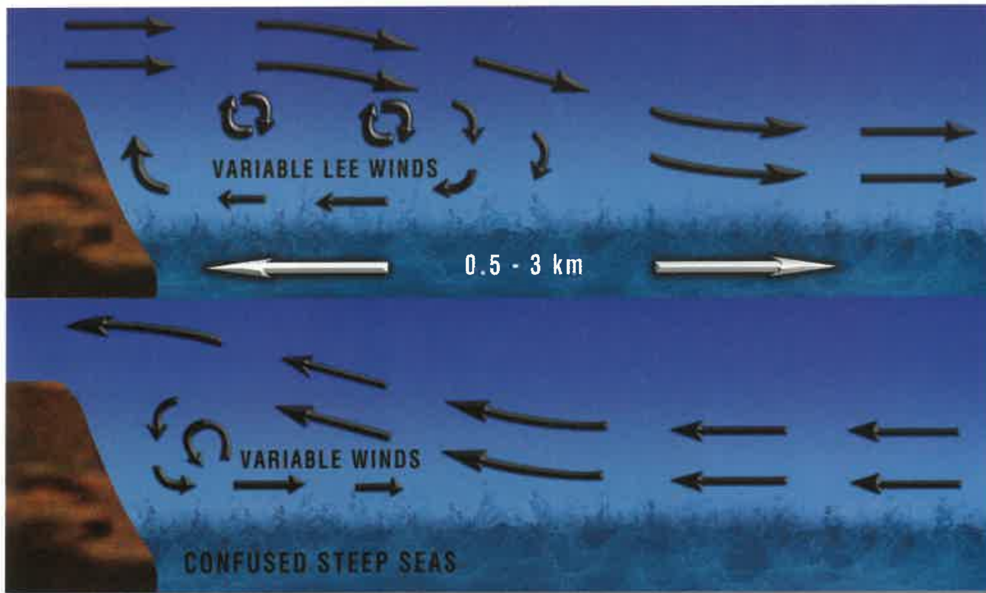
Cliffs or steep shoreline bluffs may also cause local wind effects that warrant caution. With winds blowing in a general onshore direction they will usually channel along the base of the cliff (see diagram, right). However, winds blowing directly onshore against a cliff face may actually reverse direction, causing confused winds near the shoreline and confused, steep waves.



Deflection of onshore winds by high land.

When winds blow offshore over rugged terrain, confused or variable winds often form downwind of the cliff face, creating zones of stronger and lighter winds. With small cliffs this may only result in an area of calm near the shore (such as at the Scarborough Bluffs). With large cliffs, on the other hand, stronger, gusty winds persist near the shoreline as long as the wind direction and stability of the airstream remain constant. Farther out, there is an area referred to as a "wind shadow" with lighter, variable winds.

Cliff effects can be found on the east side of the Bruce Peninsula, where the high land may create marked gustiness. With an offshore southwest wind, there are confused winds below the shoreline and a relative calm further out. With an onshore wind northeasterly, winds will generally channel along the base of the cliffs (see diagrams, page 50). If the winds blow directly onshore, they will slow on approach and may even reverse direction at the cliff base.



Cliff effects with offshore and onshore winds.

Wind words

- If there be a cloudy sky and dark clouds driving fast under higher clouds, expect violent gusts of wind.
- The sharper the blast, the sooner 'tis past.
- The winds of the daytime wrestle and fight. Longer and stronger than those of the night.
- An honest man and a northwest wind generally go to sleep together.
- Every wind has its weather.

Wind shapes both sky and landscape in eastern Georgian Bay.

Fine-tuning the forecast

When you are heading out on the water, remember – the Environment Canada forecast is only a starting point. Local winds are the result of a complex interaction between general wind and the local topography.

Are you up to the challenge of applying what you have learned about nearshore effects to your local situation? This example, at Christian Island shows how you can take the forecast and fine-tune it to reflect the unique features of a specific location. Read the text (opposite) carefully, and then try your hand at doing the same for your favourite waters.

This example is from the Christian Island region west of Midland on Georgian Bay. The entire east side of Georgian Bay is a heavy recreational area with thousands of points and small islands that play havoc with local winds.

In our forecast scenario the general winds in the nearshore area (Meaford to Parry Sound) are forecast to be southwest 15 kts. The diagram shows the winds that are likely to be observed in the local area. Note that wind directions and speeds (marked inside arrows) can vary rapidly over relatively short distances. In this example there are no onshore breezes, but if it were a hot summer day there would be – and they would further complicate the situation.

Using your knowledge of how local topography affects the winds, you can fine-tune the forecast winds to fit your location.

The diagram shows height contours every 25 m. Notice that some of the shorelines are quite steep, particularly the Georgian Highlands, where the land rises over the 50 m from the water in less than a kilometre.

The winds in Christian Channel have been bent from southwest to southerly by the steep cliffs. Funnelling and shoreline convergence have also caused winds to speed up through this area. Funnelling extends further from the shore with larger cliffs than it does with smaller ones. The stronger southerly winds would extend out 1-2 km from shore in this case.

At Cedar Point boaters would find that wind speeds increase dramatically. This steep point of land, when combined with Christian and Beckwith Islands, forms a good funnel. This generally increases southwest winds to 20 kts through the whole channel and 25 kts within 500 m of Cedar Point.

Continuing eastward, at the mouth of Thunder Bay the winds are likely to be gusty and unpredictable. The valley that extends inland from Thunder Bay would give rise to gusty southerly winds that might surprise a boater heading across the mount of the bay. If there were an onshore breeze, the winds in this area would be further complicated.

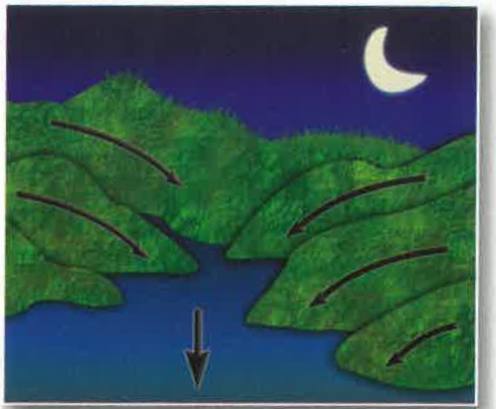
Near Christian and Beckwith Islands winds to the lee of the sloping shores or cliffs would be light and variable in direction, due to the lee or cliff effect.

As this example demonstrates, winds around the Great Lakes can be very complex to understand and predict. However, as a boater, if you are aware of the general forecast conditions and attentive to local influences, you will be better equipped to understand the changing winds so that you can use them to your advantage.

There are several points you should keep in mind if you are to make the best use of the forecast:

1. Do you have the right forecast? – the right type for the right area?
2. How will the topography in your area influence the general wind? – Consider effects such as channelling, funnelling and valley winds, as described on page 46 and 53.
3. Is there likely to be an onshore breeze? This is likely if there are relatively warm temperatures over land and cool ones over water. See page 43 for a discussion of lake breezes.
4. Will the size of your boat affect the wind you perceive? Low lying craft such as sailboards, powerboats and small sailboats may experience lighter winds than were forecast due to the marine inversion (see page 42).

Valley winds (katabatic and anabatic winds)



Katabatic Winds.

Anabatic winds.

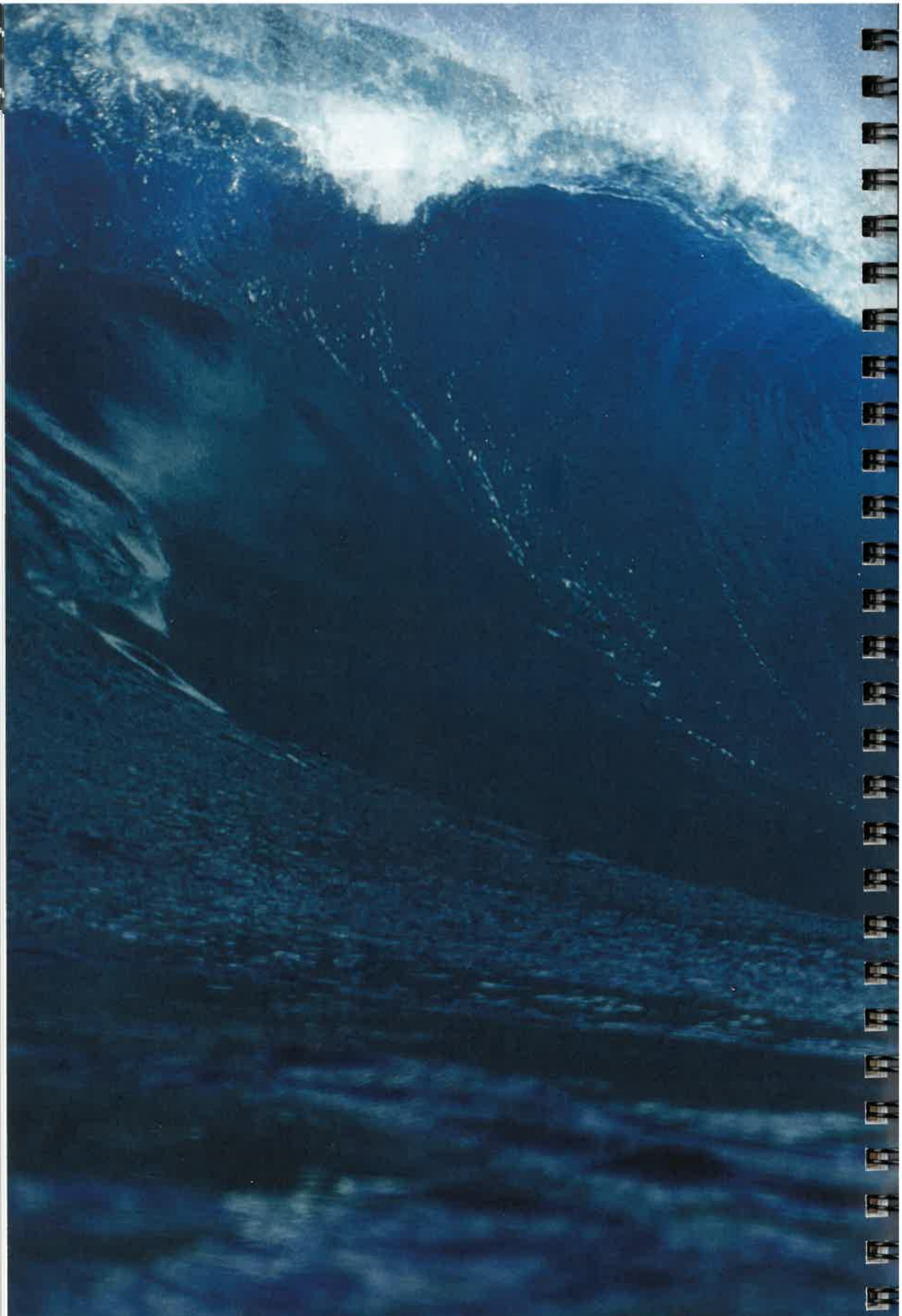
Valleys are ideally shaped to channel and funnel winds, especially when their walls widen gently into a harbour or basin. Strong gusty winds can funnel out of the valley and surprise boaters near the mouths of such harbours. However, there are two related valley wind phenomena that are more subtle but no less powerful: katabatic and anabatic winds.

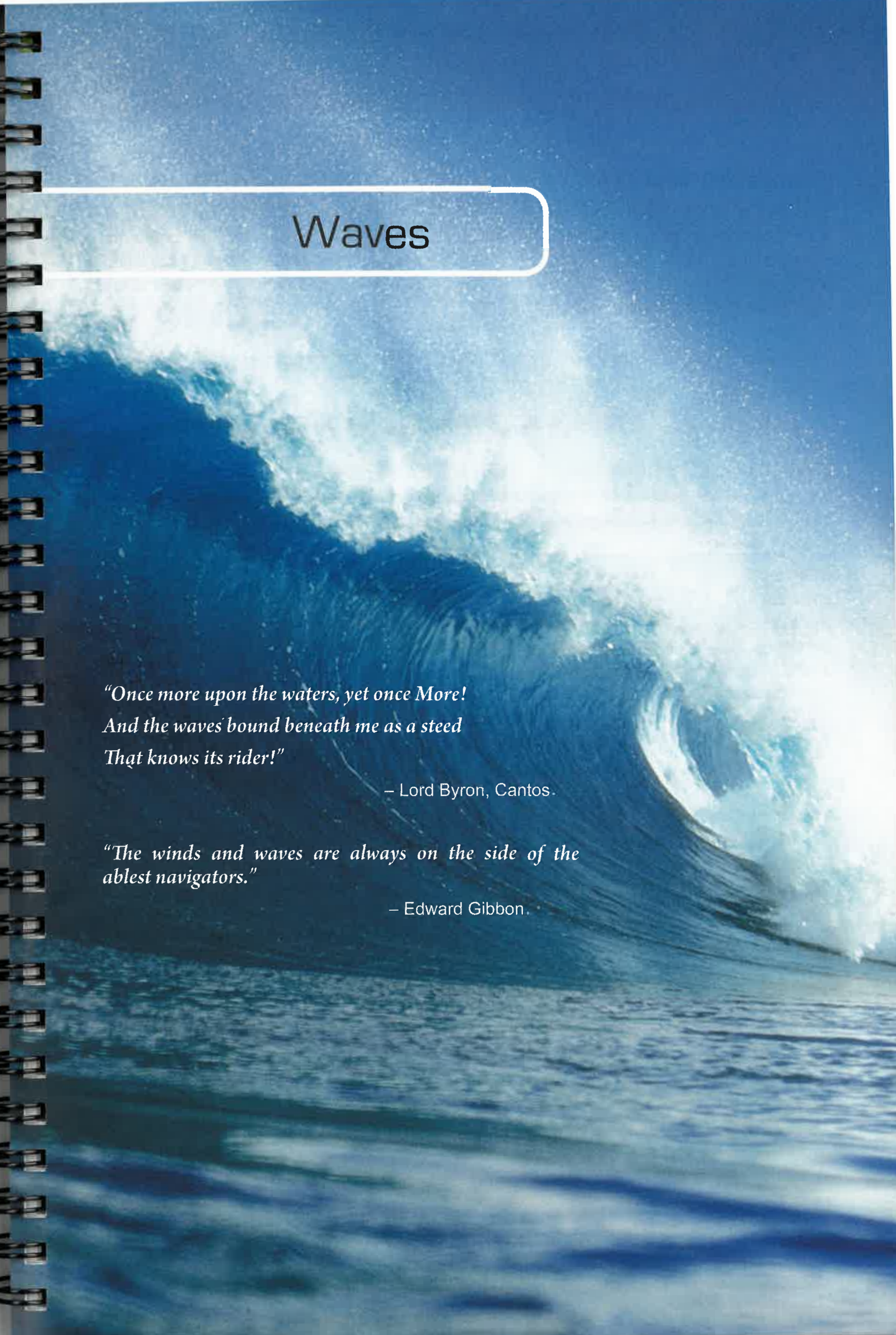
The boater who takes shelter in a secluded cove in the evening may be surprised to awaken to sudden, strong, gusty winds in the morning. This effect is caused by a type of valley wind. At night, the air cools over higher terrain and sinks to the valley floor (top diagram). This process sets up cool night winds that are called katabatic or drainage winds. They are often quite gusty and are usually stronger than their daytime sisters, anabatic winds.

During the day, the sun heats the sloping sides of valleys, making them warmer than the less exposed valley floors. As a result, the winds blow up these slopes (and up the valleys) during the day (bottom diagram). These winds are called anabatic winds. The strongest anabatic winds are found when valley sides slope gently and face the south, thus getting maximum daytime heating.

Anabatic and katabatic winds can join forces with land or lake breezes to make them stronger. They can also produce surprisingly strong gusty winds by accentuating funnelling in river valleys ranging in scale from the St. Laurence to the Rouge River Valley.

> ***"We found ourselves in a confused sea....***
> ***The river mouth opened up a white-capped vista of waves and wind.... We found ourselves in a confused sea, as the long-driven waves piled up on a shallow, rocky shelf."***
>
> – Tim Dyer in QAYAQ, Summer, 1990.
>
> Boaters entering or leaving narrow waterways (rivers and canal systems) should be alert to the interaction of valley winds with funnelling and current. Seas can be very confused and choppy under these circumstances, and are sometimes further complicated by shoaling and a long fetch.





Waves

*"Once more upon the waters, yet once More!
And the waves bound beneath me as a steed
That knows its rider!"*

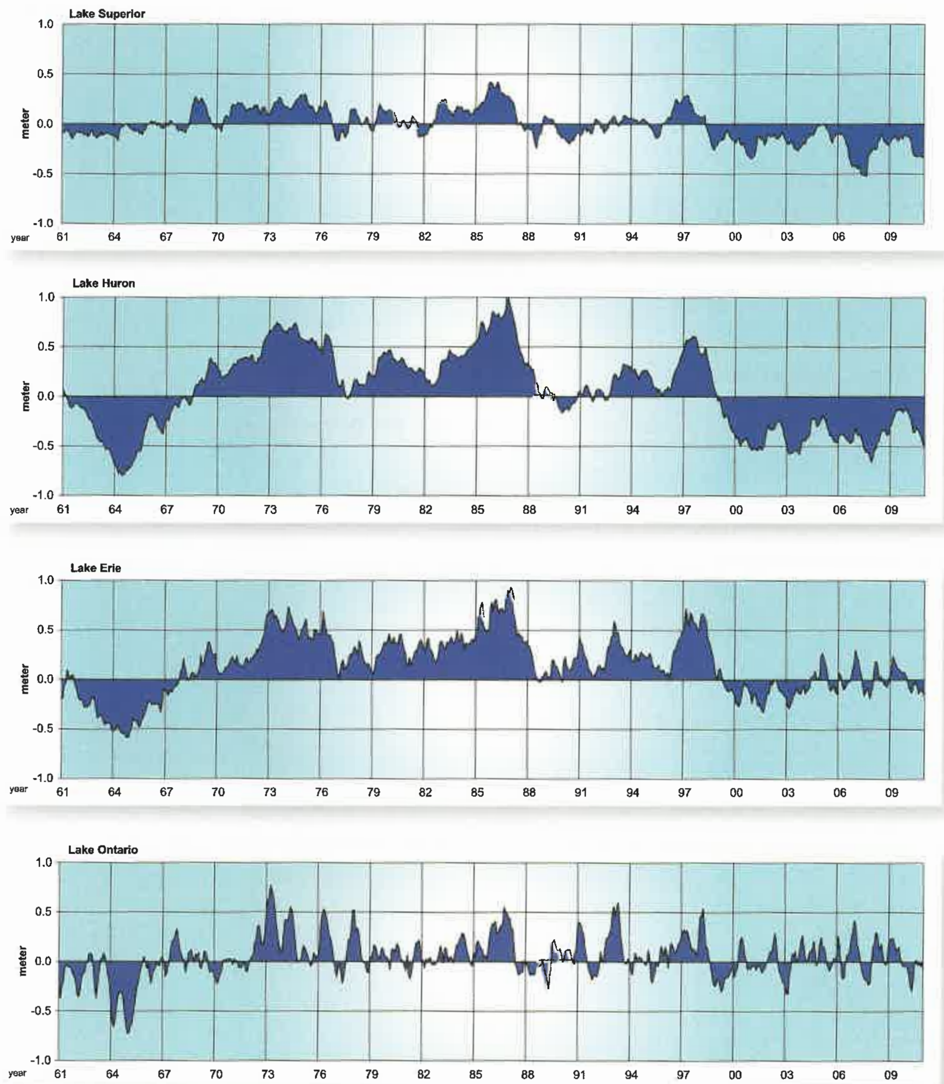
– Lord Byron, Cantos

"The winds and waves are always on the side of the ablest navigators."

– Edward Gibbon

Changes in Water Level

Water levels in the Great Lakes rise and fall significantly over both long and short periods of time. It is important for boaters to be alert to changes in water level, whether they are long-term, seasonal, from day to day, or from hour to hour. Shoals and shallows can present risks when the waters are low, and extensive damage may be done to docks and moorings when storm surges cause dramatic rises to occur.



Variation of lake levels over time with respect to chart datum.
Data courtesy of : Environment Canada (Great Lakes – St. Lawrence Regulation Office)

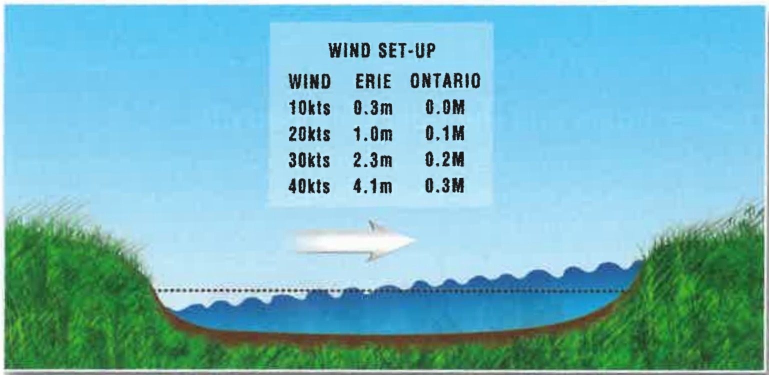
The overriding factor in seasonal water level fluctuations is the balance, or imbalance, of precipitation and evaporation. Overall, the precipitation and evaporation rates tend to balance out, but long-term, annual and seasonal imbalances result in rising or falling lake levels. For example, wet years had caused very high water levels during 1997. Another spell of wet weather could push levels up to near-record values again. Fortunately, the Great Lakes region has quite a moderate precipitation regime and each year's natural decline in water level easily regulates most surpluses.

More important to boaters are the daily fluctuations caused by wind (wind set-up and seiche) and local jumps caused by pressure changes in thunderstorms.

Wind set-up and seiche

If strong winds blow down the length of a lake, water is pushed toward the downwind end of the lake, piling up there. The amplitude of this wind set-up effects is related to the shape and depth of the lake, and it is more pronounced on shallow, elongated lakes like Lake Erie (see diagram, below).

When strong winds cause a major set-up, with a sharply peaking maximum water level at the downwind end of a lake, this peak level is called a surge. On shallow Lake Erie 30 kt winds along the axis of the lake produce a 2.3 m set-up, with storm force winds raising levels as much as 4.1 m. On the rest of the Great Lakes, wind set-ups are generally less than 20 cm. However, funnel-shaped bays or harbours with gradually sloping bottoms may amplify the set-up effect, resulting in greater changes in water level (as can happen at Sault Ste. Marie, on Lake Superior).



How wind setup varies with wind speed and lake depth for shallow Lake Erie and deeper Lake Ontario.

When the winds that caused a set-up weaken or change direction by 45° or more, the water flows back down the lake. Imagine a basin of water being tilted so that the water becomes deeper at one end and shallower at the other. (See illustration above.) Now, imagine it being placed back on a level – and the resulting sloshing back and forth of the water until it eventually settles back to its original even level. On a lake, this continuing oscillation of water is called a seiche. Although the force that causes it is different, it is very much like the sloshing water in the basin. Successive peaks decrease in height as the seiche slowly subsides over 1-2 days. If strong winds re-establish themselves along the axis of the lake before a seiche has dampened out, they can quickly re-amplify the pattern to produce a significant wind set-up.

Because it is long (388 km), but shallow (average depth of 19 m) Lake Erie is particularly prone to shoreline flooding and damage to docks and moorings from surges. It also suffers a corresponding problem with low water on the west end during seiche events. This, too, can be significant, as it may result in the exposure of shoals and increased risk of being grounded in shallow waters. Seiches on Lake Erie oscillate on a 14 hour interval between maximum water levels. Approaching deep low pressure centres with east to northeast winds can cause wind set-up on the west end of the lake. If the wind shifts to southwest gales with the right timing, a magnified surge arrives at the east end with unusually high water levels and extensive flooding.

The rapid changes in barometric pressure and wind speed that are often associated with thunderstorms can create small-scale surges in bays and harbours, and these may combine with local waves to create difficult boating conditions. This effect will be most apparent when a storm with a heavy wind squall is situated near the mouth of a bay or inlet.

Wind set-up raises the overall water level, but it is important to remember that wave effects (see *Waves*, page 60) are superimposed on this. Four metre waves on top of a 1 m surge can damage many vessels and moorings. Rises in water level due to wind set-up are also affected by local shorelines. Bays with a wide entrance tapering and sloping towards shore will see larger set-up and seiches, and this situation will be aggravated by high waves if the bay faces the wind. The wise boater will be particularly on alert for high seas and damaging waves when a significant set-up or surge is occurring.

"Several power boats had their decks ripped off…"

"We had a very strong storm front come through and a very strong south wind came through with it, and it literally sucked all the water out of the harbour. …Boats were hanging by their cleats, and I was on the bottom. Most of the other sailboats were on the bottom. About 4 hours later, when the winds subsided, the water came rolling back with a vengeance – and it all sloshed back in. We gained 2 feet and it was rather nasty. We had to have everybody down there on the dock lines.

Storm surges and seiches occur in all the Great Lakes, even Superior on occasion. U.S. geologists, J.W. Foster and J.D. Whitney, reported that one and a half centuries ago: "In the summer of 1834, an extraordinary retrocession of the waters took place at Sault Ste. Marie. …The water retired suddenly, leaving the bed of the river bare, except for a distance of about 20 rods where the channel is the deepest, and remained so for the space of an hour… The return of the waters was sudden and presented an imposing spectacle. They came down like an immense surge – roaring and foaming; and those who had incautiously wandered into the riverbed had barely time to escape being overwhelmed."

– stories and quote from Steve Donker.

Waves

"Once more upon the waters, yet once more!
And the waves bound beneath me as a steed
That knows its rider!"

– Lord Byron, Cantos.

"The winds and waves are always on the side of the ablest navigators."

– Edward Gibbon.

"It doesn't take an awful lot"

"These lakes are very large, and because of the long fetch it doesn't take an awful lot of really strong wind to create quite a sea. And the seas are shorter. By that I mean that the wave height may be two or three feet. If you had that on the ocean, the crests might be forty feet apart – but here they are about fifteen feet apart. So you've got walls of water. Each wave is very steep, and it makes a much more difficult boat handling situation."

– Marc Raymond, boater on eastern Lake Ontario.

Whether you are looking to ride the waves or steer clear of them, it pays to know what you are likely to encounter, when and where. Environment Canada's offshore marine forecasts give average mid-lake wave height (the average heights of the highest one third of waves, measured from trough to crest). However, wave conditions may vary considerably from these forecast wave heights when you are near shore because of variations in the slope of the lake bottom. And larger scale phenomena such as currents and wind set-up can combine with local wave conditions to stir up confused and chaotic seas.

On the Great Lakes, waves are primarily wind-driven, with swell being much less significant than on the open ocean. Wind waves are created by the force of the wind on the water. How large these waves become depends on:

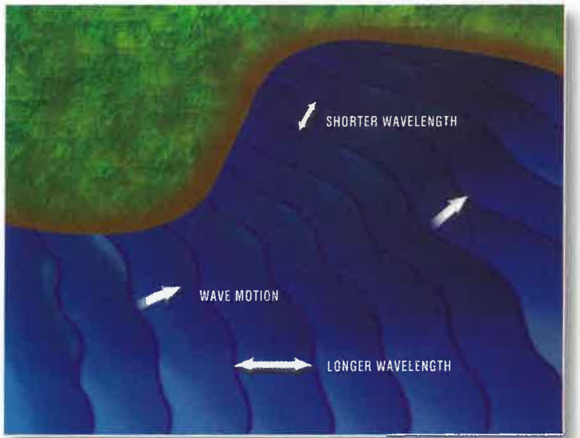
- the wind speed,
- how long the wind persists without changing direction (duration),
- and the distance the wind has been blowing over water from the same direction (fetch).

Swell refers to waves that are no longer being built or supported by wind. Decaying swell continues across the lake after the initial driving wind has shifted or died. These rolling waves move in the direction of the wind that generated them. For this reason, after a sharp windshift, confused, steep seas may last for several hours as new wind driven waves combine with the old swell. This is especially true at the northeast ends of the lakes after a cold frontal passage.

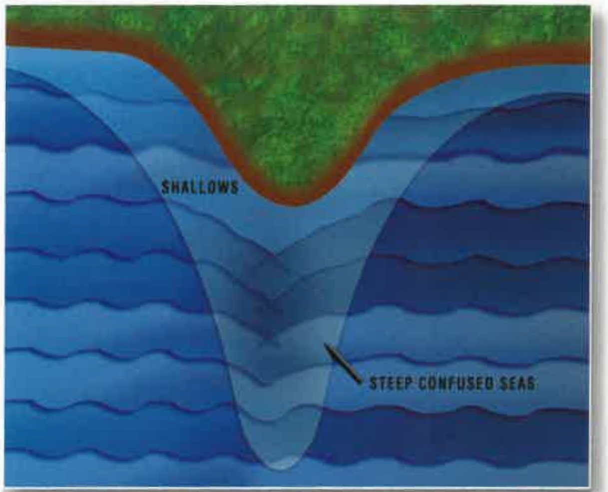
Wave patterns and effects

Waves do not exist in isolation. They interact with land features, the lake bottom, currents, and even with each other. When they approach land they can break, reflect or refract.

A breaking wave, or breaker, is one which has broken into foam or surf. This most commonly happens when waves encounter land, either at the shoreline or when they “feel bottom” as they pass over shoals or shallows. Waves can also break well away from shore. Strong winds blowing over a considerable fetch can also build waves to the point where they break. On southern Lake Huron waves often break somewhere near the ten fathom line, or where there is a significant depth change. This effect is called shoaling. It occurs when friction at the lake bottom slows the base of the waves, causing them to crowd closer together, steepen and tumble (falling over because their crests outrun their bases). Shoaling affects the steepness of waves, but not their direction.



Refraction – the bending of waves into bays and harbours.



The convergence of waves off points causes steep, high, confused seas.

Refraction changes primarily the direction of wave movement. When waves approach a shoreline at an angle, the part which is in shallower water will slow down due to the shoaling (interaction with the lake bottom), but the part which is still in deeper water continues at its original height and speed. This causes the waves to bend in toward shore. The refraction effect draws

"Like tiny corks on an ocean"

"The calm water around [Pukaskwa] Depot fooled us into believing Lake Superior was smiling at us again. As we rounded Pointe La Canadienne, we were hit with strong northwest gusts and large breaking waves that might delight a sailor but terrified us. Reflection waves tossed our kayaks like tiny corks on the ocean. After battling this condition for many minutes, we sought shelter behind a very small rock inland."

– Craig Zimmerman, Kanawa, Winter, 1995.

waves to points and bends them into bays – even when the winds are offshore or alongshore. These refracted waves often converge off points that extend outward under water. Since these waves build on one another they result in steep, high, confused seas. Boaters on the waters off Salmon Point, west of Point Petre (Eastern Lake Ontario) will be familiar with these "point" waves.

Reflection of waves occurs when they encounter a steep shoreline or structure and bounce off rather than breaking or refracting. These reflected waves may in turn interact with incoming waves to produce choppy seas.

Currents and wave/current interaction

Most currents around the lakes are generated by the wind and gradually respond to changes in the wind. River flows, too, can set up currents that are modified by the winds. Currents can interact with wind waves to create confused or choppy seas. When currents and waves collide, and the water is shallow, the result may be steep, confused seas. Waves can build into particularly steep and dangerous seas when currents and wind waves are moving in opposite directions (for example, a current moving from west to east with waves driven by easterly winds).

There may also be confused seas when waves meet a current at an angle. For example, a current from the south along the east shoreline of Lake Huron interacts with waves coming onshore from the northwest. As a result, there are confused seas and it is often difficult to enter harbours along this shoreline. The map on page 62, shows the general pattern of currents on the Great Lakes.

You should also be on the lookout for significant interactions with river currents at estuaries throughout the Great Lakes. The Niagara River, for example, is known to produce hazardous conditions, and the water flow from the Welland Canal into Lake Ontario can also set up significant wave interactions.

It is worth noting that currents are usually identified according to the direction towards which they are flowing. For example, if a current is moving from east to west it is said to be "setting" to west.

Long-term average currents on the Great Lakes. Day-to-day currents will be influenced by the winds.

"We've had some awfully big boats go down."

"We have a particular difficulty here in that the seas get steeper and steeper and higher and higher, and the water gets shallower and shallower as you get farther from the shore because of the shoals at the end of the island. So you get a very mixed up sea condition. ...We've had some awfully big boats go down in that area."

– Marc Raymond, boater on eastern Lake Ontario.

Seeking shelter

Before you set out make sure you know what safe harbours and anchorages there are along your route because you may need to take shelter unexpectedly. Not every harbour is safe. Sometimes valley winds or funnelling cause unusually gusty and choppy conditions in bays, inlets and estuaries. And shoaling can make wave conditions worse just outside a harbour, than they are elsewhere.

Make a mental note of harbours where offshore winds may create a wind shadow, providing calm anchorage. Note harbours and bays with narrow mouths and shallows (such as sandbars) at their openings, for these will give safer shelter (once you get into them) than harbours that are open to the full onslaught of onshore wave action.

When you leave a sheltered harbour, remember that conditions may be very different a short distance away. Don't be lulled into forgetting the wave conditions outside the harbour. Get an update on the marine forecast.

photo credit: Jim McMullen

This little inlet on Georgian Bay could provide as a good shelter to hold out in during a storm or to wait out strong winds.

"Pick your anchorages very carefully"

"You have to pick your anchorages very carefully around an island like ours. There are nice bays that are good for everything but a blow from the northeast, for example, and then they are wide open to the weather there. So you've got to balance a lot of factors."

– Peter Trueman, boater on Lake Ontario.

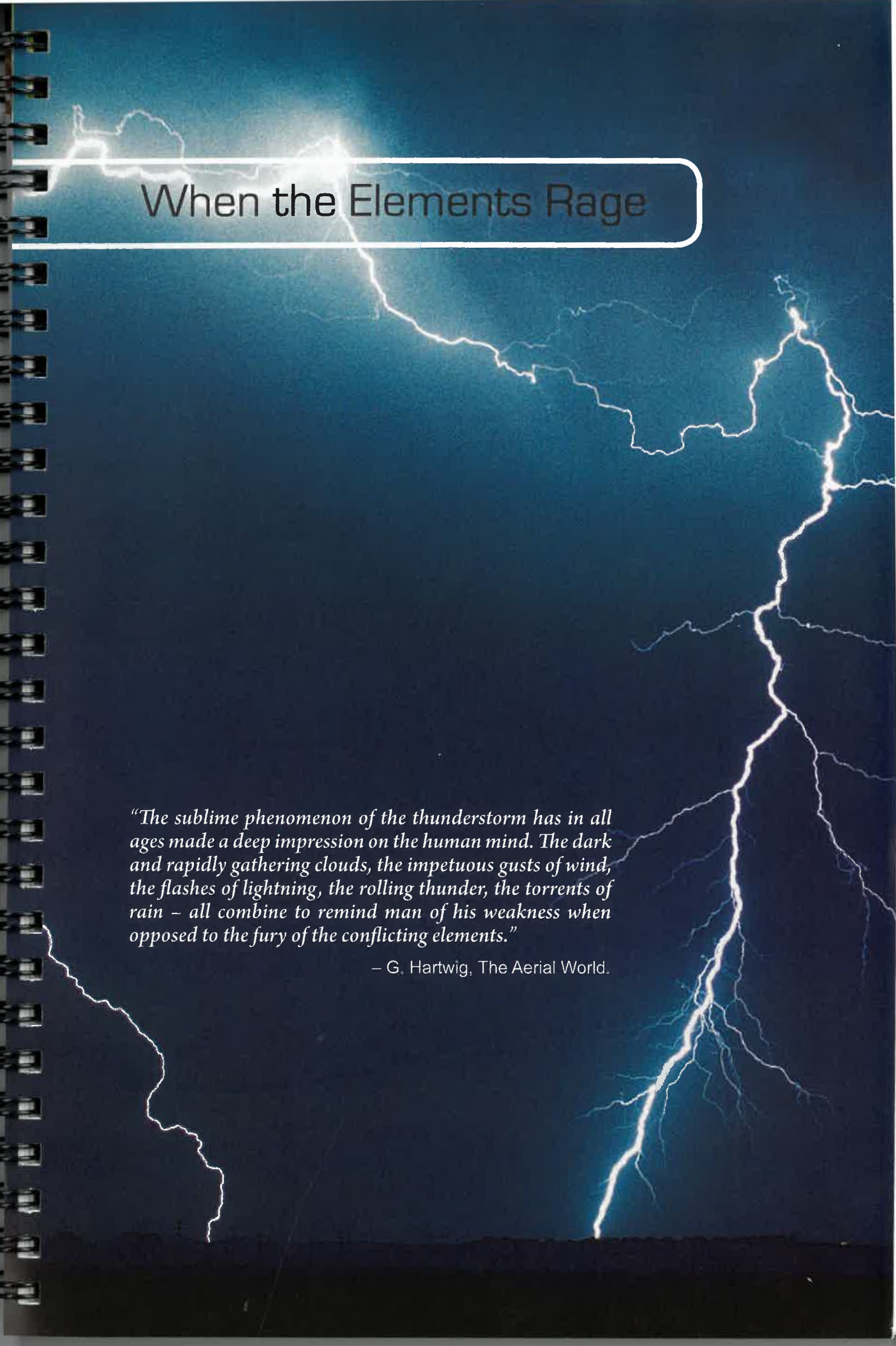
Riding the wind

Windsurfing – riding the wind and the waves, with very little between you and the elements – can be exciting. But it is important to remember that "those who do it well, do it right." As with boaters, you need to give the elements the respect they deserve. One Coast Guard coxswain commented that they have found windsurfers lying alone and hypothermic on their boards, in danger of being blown out so far that there was little chance they would be rescued.

Here are a few tips to help catch the wave without catching your death:

1. **Check the forecast and local wind conditions before you set out, and rig accordingly.** The weather can be your best friend or your worst enemy. Before you venture out, do a quick test near shore to make sure that the rig you have chosen works for the conditions. Check the direction of the wind, so you know where to launch. Look for onshore or cross-shore winds – offshore winds can carry you out beyond help. Remember that some of the wind measurements reported are taken at a height of 10 m, and winds may be different at the water surface, where you will be.
2. **Make sure you know what hazards you can expect locally.** Read up on nearshore effects such as funnelling (page 46), channelling (page 46), cliff effects (page 49), and nearshore wave conditions (page 60) such as shoaling. Talk with other people in the area about danger spots.
3. **Make sure that you have the right clothing and sun protection for the conditions.** Even on a warm day windchill and spray can cause hypothermia (see page 87), and windsurfers are sometimes tempted out into the winds and waves of the early and late season, when bitterly cold air and/or water can be dangerous. A good rule of thumb is: when your hands get stiff and cold, it's time for a break. Stay close to shore so that you can get in quickly if you need to.
4. **Wear your PFD (Personal Flotation Device) and whistle, as required.** And make sure that the PDF will be easy to spot if you need rescue (brightly coloured or with fluorescent tape on it).
5. **Sail with a buddy. If you must sail alone, file a sail plan with someone you know and trust.** You are not likely to be rescued if nobody knows you are out there!
6. **Know your limits.** Windsurfers are always trying to push themselves and their equipment. That's part of the challenge. But only a fool pushes beyond his or her limits without help close at hand.

When the Elements Rage



"The sublime phenomenon of the thunderstorm has in all ages made a deep impression on the human mind. The dark and rapidly gathering clouds, the impetuous gusts of wind, the flashes of lightning, the rolling thunder, the torrents of rain – all combine to remind man of his weakness when opposed to the fury of the conflicting elements."

– G. Hartwig, The Aerial World.

Many boaters find it exhilarating to challenge the wind and the waves, but when the elements begin to rage, the better part of wisdom is humility.

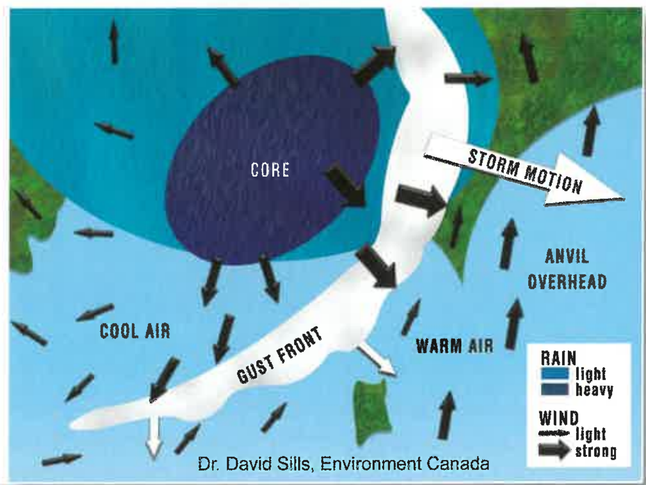
Fierce winds, churning seas, nerve-shattering lightning, icy waters and blinding rain can test even the ablest mariner beyond his or her limits. Knowing what to look for and when to expect it can give you enough time to make it to safety, before your are challenged beyond your limits.

Thunderstorms

The Great Lakes experience 15-35 days with thunderstorms each year. A few of these storms become severe, with hail, high winds, and intense lighting posing a great hazard to boaters. You should take all thunderstorms seriously, though, because each one has the potential to surprise you with fast-changing weather and unpredictable, squally winds.

The thunderstorm cloud

A thunderstorm is a cumulonimbus cloud (Cb) with specific, recognizable features and effects. When a storm is near, try to size up what part of it you are looking at (using the table and photos, pages 71-74) and decide what is likely to occur next. The Cb is often accompanied by other clouds which can obscure your view. In that case, look for the most obvious signs (anvil cloud aloft, dark low clouds, heavy rain, and lightning/thunder) to guide you. Many isolated mid-summer storms simply grow from a cumulus tower into a thunderhead which forms a heavy downpour, then slowly



An example of a strong thunderstorm and its associated winds and precipitation, viewed from above. The moderate, warm, south-southwest flow is replaced by strong, gusty northwest winds and cooler air behind the gust front. Notice that winds near the storm tend to flow away from the heavy rain area in all directions. Depending on where you are relative to the storm's core track, the gust front can be intense and near the heavy rain or weak, with a gentle wind shift and no weather close by. The gust front will arrive quickly (it is very low and emerges from the haze) and may have a smooth, banded, light forward edge. As it nears, you will also see ragged bits of cloud below the dark base. If it is lighter again behind this cloud line, expect a brief event and mixed clouds in the cooler air but if it is uniformly dark, an intense storm will follow. The heavy rain core will always be apparent as a slate-grey, smooth (no detail) wall, usually with lightning. (See photos pg. 72 for examples of the above.)

dissipates. Others, including most frontal storms, undergo an evolution whereby new storms are always forming beside older ones. This cloud system has its own wind pattern, with warm air entering on one side to form new clouds and cool air coming out with the rain as a gusty squall.

What will you see when a storm moves in?

The anvil overspreads you first, changing the sky from bright to a leaden grey. This change is often hidden from view by lower clouds or haze. Next, you will hear soft, rolling thunder, accompanied initially by light rain. If the sky is uniformly grey, the rain will gradually increase, as will the lightning. You may experience a wind shift and cooling breeze (weak gust front). After the core and heaviest rain pass, the sky may remain stormy looking with brief showers and thunder, then brighten. This is a typical, isolated mid-summer storm without an associated sharp gust front. It arrives slowly, peaks, then ends.

With more intense storms and squall lines, the anvil thickens well ahead (sometimes several hours) of the approaching storm. There may be some light rain or distant thunder, but before heavy rain and thunder begin, a very low, dark cloud line appears and rushes in. As this gust front nears, you will see ragged clouds along its base and a smooth, dark-grey rain curtain with lightning bolts behind it (the core). A strong wind squall and sudden wind shift occur as the gust front passes you. This is followed shortly by a deluge which gradually decreases to lighter rain and softer thunder. These storms arrive and peak suddenly, then decrease slowly. This progression is typical of all squall

Visible parts of a thunderstorm

The **anvil** is a long cloud plume extending forward from the storm (out ahead of it). It looks like a grey altostratus cloud sheet when overhead, and is your first indicator that an organized storm is approaching. The anvil is your advance notice to take action and find safe shelter.

The **core** of the storm is the dark area under it where the heaviest rain, hail, and lightning are. If strong winds exist, they will occur just ahead of the core or with it. Your greatest risk with this part of the storm is lightning, strong wind gusts, and very heavy precipitation reducing visibility. When you see this part of the storm to your northwest closing in, assess the clouds for the presence of a gust front and (if there's time) steer left and away from it to avoid the strongest winds. These will occur just ahead of and on the southeast side of the core (see page 66).

The **gust front** is a low, dark cloud line that moves in rapidly with brief strong winds, usually just ahead of heavy rain and lightning. The more ragged looking and low the cloud line is, the stronger the wind squall is likely to be. The gust front can move out far from the storm (usually to the east or south) where it will slow down and weaken. In this case, the cloud bank may be thin or absent and the winds lighter. With many gust fronts, the cloud bank grows into new storms separate from the original one. Your greatest risk with a gust front is a sudden increase in wind speed, an abrupt change in direction, and choppy waters.

lines, most cold fronts, and a few isolated storms.

With a special type of very intense storm called a 'supercell' storm, the worst part of the storm comes last. As with the other storm types, the anvil thickens well ahead of the storm. There may be some light rain or distant thunder, but both increase gradually over time. Rain then becomes very heavy and is followed by hail, possibly up to the size of golf balls, tennis balls or even base balls. Then the precipitation ceases and there may an eerie calm. The intense storm updraft is nearby, and it is at this point that you should be on the look out for a tornado.

Weather Watches and Warnings

A **severe thunderstorm watch** is issued for a region when the potential exits for the development of severe storms. It is an alert to the possibility of their formation and usually covers a 6-8 hour period. During a watch, you should monitor changing weather conditions. If individual storms intensify to the severe stage, **severe thunderstorm warnings** will be issued for local areas in their path. If your location is cited in a warning, it is time to take action and get off the water because a severe storm already exists and will likely move in shortly. Your area can expect strong winds, very heavy rain and lightning, and large hail.

Tornado watches and warnings occur a few times each year in Southwestern Ontario. Tornadoes usually dissipate when tracking over large lakes but the storms producing them will still be dangerous over water; likely including strong winds, frequent lightning and heavy rain. (See also *Marine warnings*, page 130)

Isolated summer thunderstorms

On warm, moist days from June to August in a weak pattern, isolated storms can form during the day and last for an hour or two. They almost always form over land, sometimes along lake - breeze fronts or over higher terrain, and will weaken if they move out over the water. With storms typically moving from the west quadrant, this means that the east sides of the lakes are mostly storm-free during this type of weather pattern. This is especially true earlier in the season when the lakes are still cold. Later, when the lakes are warmer, the weakening effect decreases. Lake Erie and Southern Lake Huron become quite warm in August and storms can persist over the water there. Late in the season, cold spells can lead to cloud build-ups and isolated, weak thundershowers forming over the warmer waters.

Tip ✓

In stormy weather, it is best to stay away from the windward shore when passing through islands. It is safer to chance drifting into the open than onto the rocks when a problem occurs. Passing on the lee side buys you time and decreases the risk of personal injury or damage to your boat.

Movement is often slow, but the sky and clouds will change quite a bit. The storm cloud is sometimes visible by itself, but more often you'll see the anvil cloud spreading out or moving overhead, with lower cumulus growing under and around it, especially near the rain. The main part of the storm will remain near shore and only give a brief period of heavy rain and lightning.

If the downpour pushes cool air toward you, it may arrive as a wind surge with a bank of dark clouds. In this case, watch out for a brief period of gusty winds coming from the storm, and for new showers (and lightning bolts) forming out of the dark clouds above you. You can monitor storm activity by listening to the crackles of radio static on the AM band from lightning discharges.

Frontal thunderstorms

Most thunderstorms in spring and fall accompany cold fronts and are either embedded in a larger rain area or part of a squall line (see page 75). These can occur either day or night, but the storms are usually stronger during the daytime. In the summer, most storms accompany cold fronts and are more active from late afternoon into late evening. However, warm fronts can also have storms with them but they are often more active late at night. These storms are embedded in cloud layers, making them harder to detect. In spring and fall, frontal storms move more from a west to northwest direction. You will notice that the clouds themselves often move from the southwest, even though the front and storms arrive from the northwest.

As a cold front nears, lines or groups of storms will form along and ahead of it. The storms often need the extra heat of the afternoon to get going, and will be most intense and widespread late in the day. If the front passes at night or early in the morning, there may be only a band of cloudiness and a few showers with it.

"A storm suddenly came in..."

"It was about the end of July and we were out racing. We had just rounded the windward mark and were heading for the jibe when a storm suddenly came in. We turned around, jibed around, actually, to head in back here, and then we dumped because it was blowing pretty hard. And we lost our daggerboard. It fell out, so we couldn't right our boat. So we just waited the storm out until it was over.

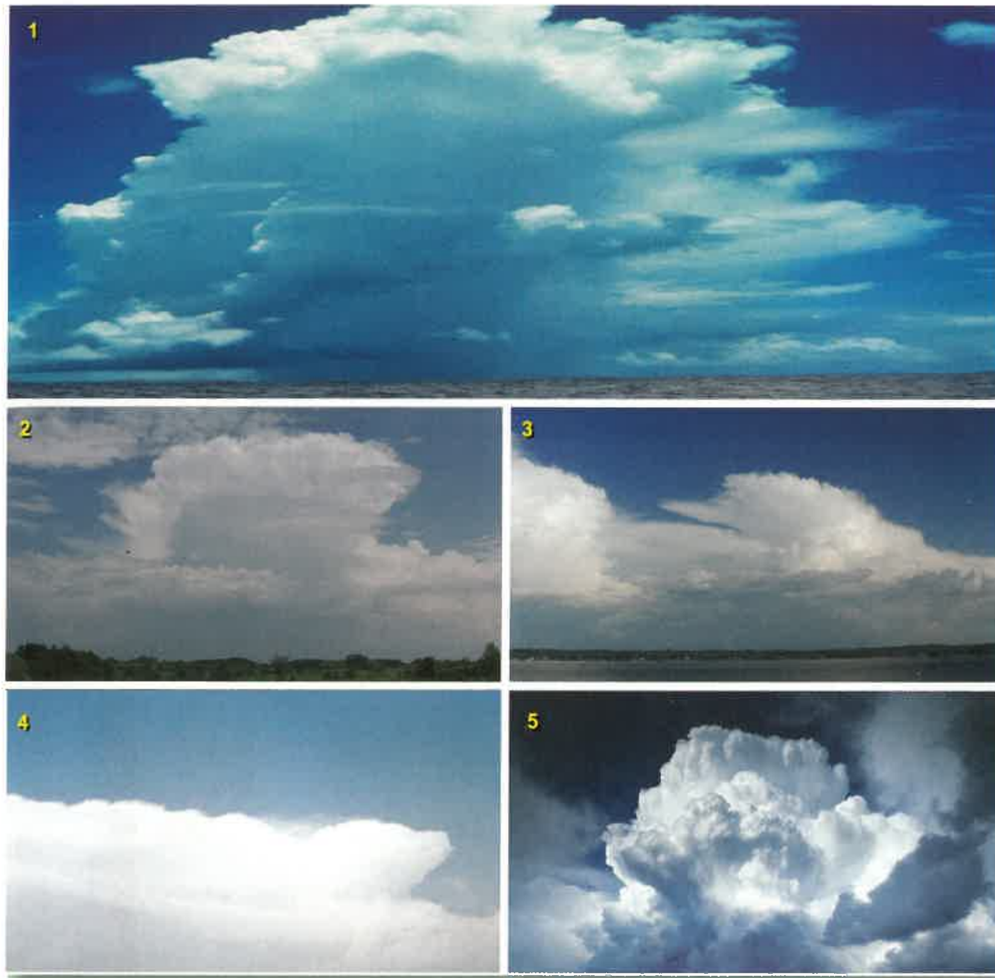
A distant storm has sent out a burst of cool air which is now approaching quickly with a line of rowing dark clouds.

"There was 30 to 40% chance there was going to be a storm, and I saw the black clouds – like, they were pretty far away, though. So I didn't expect it to come – I expected us to finish the race before it hit.

"You gotta be really aware of what the weather's like. If it's cold or if it's going to storm, you shouldn't be going out. And especially if the water's cold, you should be wearing a wetsuit or a drysuit." – Sean Hewson.

In general, frontal storms give us more forewarning because sky changes begin well ahead of the front or storms with it. Nonetheless, local conditions can change suddenly as new storms build around you ahead of the front. The effect out on the water is exacerbated by hazy skies, fast-moving clouds, and increasing winds. As well, frontal weather affects your entire area so it is difficult to avoid.

Frontal storms can become severe and dangerous, and can survive over the lakes. They often propagate forward (new storms form out ahead of older ones) which means you may misjudge your safety margin. An approaching storm with a fast-moving cold front will not only move in quickly, but may be building forward as well. The clouds out ahead of the advancing rain can build quickly into new storms, with surprising wind gusts and lightning where there were only dark bases minutes before.



A storm is coming!

In **1**, an isolated storm is preceded by many growing cumulus (dark bases) which may become new showers soon. These clouds were formed by the cool air coming out of the rain (gust front), which will arrive soon well away from the storm.

The first signs of an isolated storm **2** may be hidden by other clouds or haze on a typical humid day. Only dark bases and/or thunder will help you notice it. If a cold front or squall line is coming, towering cumulus and anvils will invade the sky **3**. In **4**, an anvil is spreading in overhead. Because it is an isolated storm, it doesn't have many lower clouds with it. It will build gradually, peak, then end. If both high anvils and lower cloud layers thicken together **5**, the storm is likely to be part of a line or more extensive event and could be strong. In this case, warm air is being lifted ahead of the line, forming new (black) clouds out ahead of the existing storms. This is how squall lines grow forward and are able to move so fast.

The gust front – a sudden wind and storm

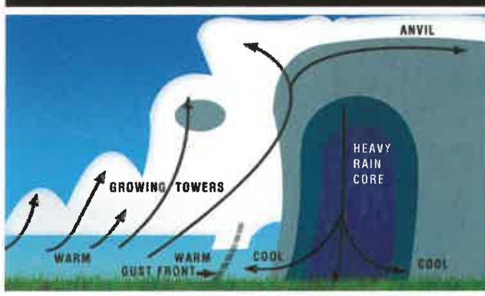
Many storms arrive abruptly, with racing low clouds and a gusty wind. The gust front in **1** has surged a few minutes ahead of the heavy rain at right. A fast moving mass of low cloud with ragged fingers under it marks the leading edge of the cold, gusty wind.

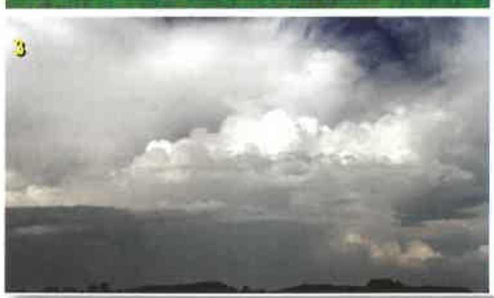
A typical gust front **2** on a hazy, humid day will appear very quickly as a low, dark cloud line. Any time you see very low, ragged clouds in a line moving toward you, **3** expect a sudden wind increase. All low clouds represent rising air – which often means a cool wind pushing forward. The leading edge of this cool wind will look like a low cloud bank or shelf **4** with a turbulent sky beyond it. In **5**, a low cloud strip is moving out of the rain while the tuft above is where rising air condenses as it enters the storm at right. Watch all low cloud scraps to see if they are rising into a dark base (building cloud above) or moving forward (strong wind pushing it). They tell you best what surface winds are up to.

The structure of storms – overview

A well-developed storm is a magnificent machine. In **1,** warm air rises sharply at lower right, fans out to form the anvil in successive pulses, then descends with the rain curtain. The storm survives by replacing older parts with new, maturing updrafts.

Separate updraft towers, usually along an axis, grow to maturity in a long-lasting storm **2.** The diagram shows the structure of these stages. As a tower attains maximum height, it releases a heavy downpour. While it weakens and drifts downwind (to right), another takes its place. In this way, a storm can survive many hours while constantly regenerating. From the outside looking north **3**, the newest parts are often at the west or south side, with the anvil and rain spreading northeast from there. The anvil above some storms spreads out in all directions **4** away from a powerful central updraft.





The structure of storms – underside

From underneath **1**, a storm will have a grey anvil above, lowering to a dark rain core (distant here), with a bank of low clouds leading away from it to the south or west. This bank is an axis of growing towers which will either move up and merge with the storm's core or develop into new showers. A wind shift and cooling often accompany this line.

A mixed, "messy" sky **2** has clouds at all levels with showers here and there but no real focus – and lower risk. Storms that are more organized **3** have a solid rain curtain and a bank of dark clouds around it where new development is underway. The relationship between rising air (dark, flat base) and descending air (with heavy rain) is very pronounced in **4**. This sharp contrast can lead to severe weather and high winds. A turbulent sky **5** worries many people but is usually harmless. The mottled appearance comes from small downdrafts above a cool flow, which often means the storm is weakening.

Squall line appears as a dark wall of cloud typically approaching from western horizon.

Squall lines

A squall line is a long-lasting line of thunderstorms and strong winds along or ahead of a cold front. It is a fast-moving system, with high winds presenting the greatest danger to boaters. An added risk comes from new storms which often form 1-3 km ahead of the main squall line, creating surprise downpours and lightning there. Usually, only one such line passes a given location, followed by fair weather, but you can have two squall lines go through 1-3 hours apart before the main cold front passes. Even if a squall line is not present, you can have strong, gusty winds with the frontal passage or with lines of weaker showers ahead of it.

Squall lines almost always have a large anvil cloud sheet well ahead of the storms. The sky darkness uniformly across the western horizon. At first, the clouds thicken gradually but eventually a much darker, lower mass of cloud emerges. This will approach quickly and be followed by an intense storm of heavy rain and high winds. The wind often begins abruptly with the passage of a gust front just ahead of the rain. Strong, gusty winds can persist for 15-30 minutes, during which heavy rain and lightning continue. There may be several pockets of heavy activity but once it settles down to a moderate level, it will gradually taper off and end within the hour.

Watching the stormy sky

It's in your best interest to keep an eye out for weather changes and to recognize their meaning. If you are able to determine where you are relative to an approaching storm, you can minimize your risks. Play it safe – head for shore early when you see trouble brewing nearby! The shore looks close but you would be amazed how much weather can happen in ten minutes! When the warning signs become apparent – thunder, darkening sky, cool wind increasing – don't delay!

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Stormy sky quick reference

This table outlines thunderstorm situations you may encounter and what the likely weather will be with them. In all the features discussed below, it is assumed that the storm is in the quadrant from which the weather is moving that day (usually to the west, coming towards you). Constantly check the storm's motion and position (the core area) to see if you are in its path. (For cloud type examples, see page 28.)

If you see...	This means	What to expect...	You should...
a sunny day give way to a high altostratus overcast (anvil), then showers and/or soft thunder	it will probably only be a weak thunderstorm	conditions will slowly worsen but may not be serious	listen and watch for an approaching dark area and frequent bolts or booms of thunder
thick anvil invades the sky (may be obscured), booms of thunder are heard in the distance	a strong storm or a squall line with a gust front is moving up	expect a storm shortly with sharp changes in conditions	take immediate precautions for wind, lightning, and heavy rain
you see a line of low, dark, ragged clouds approaching quickly	the gust front will arrive in a few minutes	expect a sudden wind increase as the gust front passes, lasting 1-3 minutes. If dark behind line, heavy rain squall will follow	take immediate precautions, and turn your boat to face the oncoming squall
a cool wind has set in and the clouds above are churning and turbulent, but no thunder or rain is present	the gust front has just passed and the storm's core is either weak or passing you by	winds will abate and rain may arrive a little later	maintain a watchful eye – waters will become choppy if the wind persists
sky goes very dark and calm, with thunder heard to your NW/N	there may be new storms developing overhead or nearby	brief heavy showers, then breezy, cooler, and brightening	look to N for a gust front, and to W-NW for signs of lightning or heavy rain
you hear a steady, soft, rushing sound	could be heavy rain hitting the water or a strong wind nearby	if the sound becomes louder, expect a heavy downpour and/or a brief wind squall	if there's no thunder, event will be brief but prepare for sudden wind change
you see a thunder-head or hear thunder to your S or E or N only	storm is passing by or moving away	no change where you are, but watch for wind shifts	carry on, but watch for any new development to the west
stormy weather has ended and the sky becomes clear.	storm/squall line is moving away.	if it was the front, the winds will have shifted and stay that direction; otherwise, it will remain fair several hours but clouds may increase again later.	keep an eye on the sky until the cold front has passed for sure. Watch for gusty winds along or behind the cold front.

You should pay attention to squall lines because they affect a large region and almost guarantee a strong storm which you will not want to experience on the water. Some people have used the term "line squall" to refer to the sudden arrival of the wind and rain with such a system. A squall line describes a line of storms covering a large area while the "line squall" is the leading edge winds of such a line or cold front. Since we experience the effects of a storm on a local scale (within our view), what we see coming across the water is a combination of heavy rain and wind along a line across our view. This will happen with any strong storm, whether it is isolated or part of a squall line. What we see coming as a "line" is the storm's gust front, which sometimes precedes the rain by several minutes or arrives right with it.

Keep tuned to forecasts and Weatheradio for warnings and the development of thunderstorm lines. Squall lines leave little room for escape if you're out on the water. Unlike most storms, which have brief periods of gusty winds, etc., the squall line may remain intense at your location for up to half an hour. The combination of a sharp windshift with sustained strong winds will induce sudden wave extremes and very dangerous conditions on the lake.

Lightning

Most of the dangerous lightning in a storm occurs near the heavy rain core. Even with a cloudy, hazy sky, you can estimate the direction and distance of a storm by listening for the distinct boom of a thunderbolt. Most of the bolts occur in the active part of the storm, while weaker, drawn-out thunder spreads throughout the anvil well ahead of the storm's core. However, in severe storms or newly formed cumulonimbus clouds (not much rain yet) bolts can come out of the cloud some distance away from the rain or darkest parts.

On bright or hazy days, lighting will be difficult to see beyond a short distance. The thunder, however, can be heard for up to 50 km or more and is a good indicator of the weather to come. As with all storms, the obvious things are only part of the picture. As one storm weakens and stops flashing, new towers (recognizable by the dark, flat bases of developing large cumulus) can quickly mature into new storms with lighting strikes nearby.

Being out on the lake automatically makes you a possible target. Even if your body isn't struck, a bolt can puncture the boat's hull or start a fire. Water is an extremely efficient conductor and can transport a paralysing shock from a single bolt over a kilometre away! Sailboards and dinghies should get off the water at the first sign of frequent thunder or heavy showers.

A note on lightning

If caught on your boat during a lightning storm, don't make yourself a conductor – make your vessel a conductor instead. You can do this by grounding it – clipping conducting material (e.g. a chain or jumper cable) from masts or shrouds/stays with the other end dragging in the water. Stay below if possible, and avoid contact with objects and parts of the boat which may conduct electricity (tiller, masts, lifelines).

When someone is struck by lightning, don't give up on them. Even if you can't detect a heartbeat, victims of lightning strikes can often be revived by Cardio-Pulmonary Resuscitation (CPR). A lightning strike can "shock" the heart into stopping, but CPR will usually get it going again.

A testimony to electricity's power

Although it is rare for boaters to take a direct strike from lightning, the power of an indirect strike can be life threatening, as the following incident, reported by Nigel Foster in Sea Kayaker, August 1995, attests:

"He was thrown from his kayak by the blast. By the time the onlookers reached the kayak there was no sign of the paddler. It seems he sank. He was not wearing a PFD. His aluminium paddle shaft showed burn marks. ... The cause of death was drowning."

Even an indirect strike can prove fatal when a boater is thrown unconscious into the water. Lightning storms can approach very quickly, so there is little time to seek shelter if you haven't been paying attention to the forecasts and the weather upwind.

And not all shelter is safe in a lightning storm. Foster advised:

"Do not shelter in caves, bunkers, under boulders or overhangs unless you have at least 15 feet of headroom and at least three feet on every side. Even then, keep in the huddle position against possible ground currents."

The value of this advice was reinforced by a letter printed in response to Foster's article. Gail Rondeau, who was one of four kayakers caught together in a lightning storm wrote:

"Lightning should be taken seriously. All four of us suffered cardiopulmonary arrest [when they sheltered in a concrete bunker]. Initial blindness, coma, brain and nerve damage, amnesia, and cataracts are some of the testimony to electricity's power which we have endured because of the hit. The most devastating result, of course, was the loss of someone we loved [Gail's fiancé].

"While John did not fall into Foster's category of those simply stunned by lightning, the rest of us owe our lives to bystanders who immediately began CPR on our lifeless bodies."

- Gail Rondeau, Sea Kayaker, October 1995.

Dazzling electricity off Port Elgin.

Caught in the whirlwind

Occasionally boaters are caught by surprise by waterspouts (tornadoes over the water), and the experience is not one they would choose to repeat. Here is a taste of what it's like to ride the whirlwind, from Jeff and Sue Burns:

Close up of a powerful waterspout.
(See overview next page)

"We were going to Port Dover with another friend of ours. He had a smaller performance boat. And the weather was great. The lake was flat as ice. ...We got out a couple of hours and I'd say we were about 20 minutes offshore from Dover. We saw these big clouds..., and we were watching them going across the shore and [thought], 'yeah, we're fine. We'll just hang out her in the lake and watch it go around, and once it passes Dover, then we'll pull in.

"Well, the clouds didn't move anywhere. All of a sudden they stopped and we said, 'Gee, that's sort of funny.' And it wasn't calling for any bad weather. And all of a sudden we're thinking: 'Boy, those clouds are getting bigger and bigger.

"Well, it had changed course and was coming right at us. So we decided, we'll try to outrun it. We [thought] that we could go to Erie. Well, on the way going out to Erie we blew up a drive. And were stuck out there, and by that time it was practically on top of us. So we put our cover on and we went downstairs. And our friend, we told him to go ahead, but he [said], 'No, no, I'll stay with you." And he was probably 30 feet away from us.

"My husband, Jeff, snapped up the cover ... and he didn't get it snapped all the way down to the end – he pulled it around underneath him. All of a sudden it started to rain and hail – big, golf-ball hail. ...The boat spun around, spun around again. I was down below and you could feel it going around. Within five minutes it was all over.

"We got up and unsnapped the cover. We couldn't see our friend anywhere – when he was only probably 30 feet away [before]. We figured we must have been in a waterspout. We called [our friend] on the radio and he was a good five miles away from us.

"So that's why we're pretty careful of the weather."

The following story, from Frank Koucky on the south side of Lake Erie, demonstrates the violence of experiencing even a sideswipe from a tornado on water.

"I lived through a tornado ... off Port Clinton on Lake Erie. I was entering my marina from the lake one hot summer day ... when a huge storm front came at me from the land at high speed – dark green and full of dust.

"Small boats on the beach, sand and tree branches all went straight up into the air about two hundred yards from me. I had the sails down and was motoring into the channel, so I spun the boat and ran as a perhaps 90 kt wind hit with a 'blender' effect on the water – no waves, no surface to the water at all. Just a whipped blend of water and wind.

A waterspout dangles from a showery sky.

"The wind shifted over 120 degrees instantly, blowing toward the beach, so I crawled forward with my 60 pound storm anchor on my back. I always entered the marina with the big anchor ready, as an engine failure would otherwise put us on the rocks. Hail was hitting so hard it drew blood, and my wife held the helm with a cockpit cushion as a shield against the wind and hail. I dropped the anchor, but the boat was going backward so fast that the anchor wouldn't set, even on a 300-foot nylon rope.

"Finally it grabbed hold close to the beach, which was invisible in the storm. The noise of the storm was so loud that I was almost completely deaf for several hours afterwards. I powered full-throttle to the anchor, remembering that naval vessels used that tactic in hurricanes, but couldn't hear the engine, and without a tachometer I couldn't tell what was happening to it.

"Finally, the wind went to a level where all I could do was huddle up, protect my face, and hold the helm with bleeding hands, cut from the hail. The boat was pitching so high that I could see at least 200 feet of anchor rope at once out of the water. And finally the wind lifted and spun us completely in a circle, wrapping the anchor line around the prop and stalling the engine.

"As the boat came down and hit the water from wind's lift, it vibrated like a fibreglass hunting bow does when an arrow is released – a deep, almost musical tone. But nothing came apart. We rode out the tail end of the storm backwards, held in place by our prop.

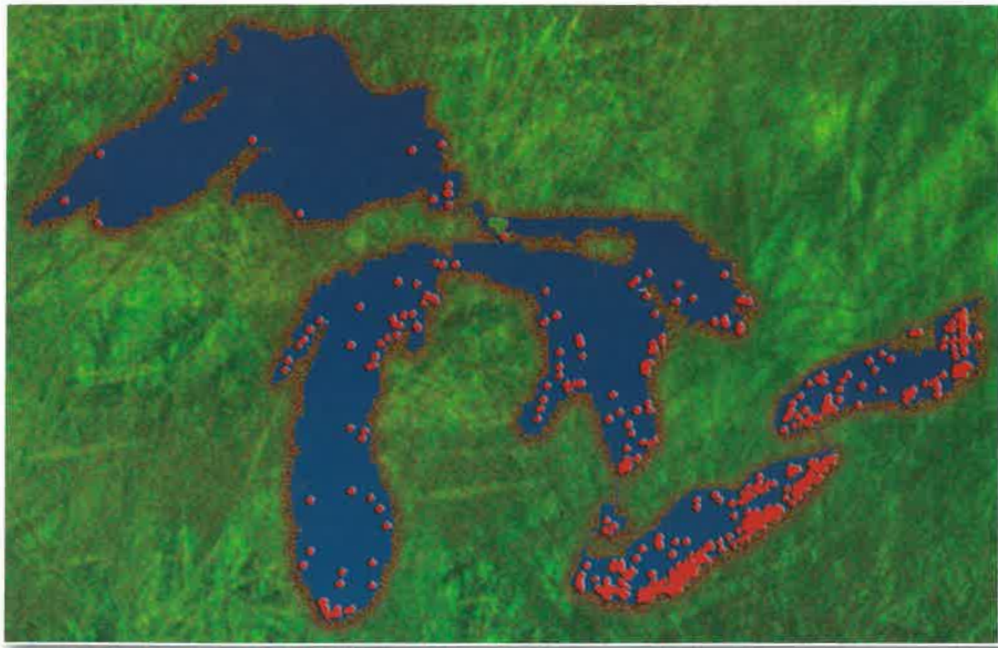
"As the storm winds diminished I got out a grappling hook and pulled up the anchor rope from below the boat, tied it off to a cleat and dived with a facemask that I keep on board to clear the prop, with my buck knife tied to my wrist to avoid losing it. I'll never forget the strange, green glass-like colour of the water under the boat as I worked on the props. I cut the line free, started the engine, and motored safely into the marina."

Waterspouts

Waterspouts are tornadoes that occur over water. They can occur with and without accompanying severe weather.

During periods of relatively cool, unsettled weather from mid-July to late October, waterspouts are possible with showers or non-severe thunderstorms over the lakes. On fair, cool days they can even occur with cumulus clouds over water. They are slender, smooth, tubular extensions below a dark cloud base and they can reach down to the lake surface where some rising spray may be visible. Such waterspouts are typically small (5-20 m diameter) and weak (40-80 kt wind vortex). They are short-lived and will move with the parent cloud. Individual waterspouts form, last up to ten minutes, then dissipate – but others may appear later under the same cloud or another cloud nearby. Such waterspouts rarely do much damage, but can flip a boat if they make direct contact. So, avoid them whenever possible by moving away at right angles if they approach you. When they come onshore they dissipate quickly.

Waterspouts can occur on all the lakes and at various times of day. They are most common from dawn to early afternoon and over the warmest waters – especially Lake Erie. Often the clouds they form under do not look all that threatening and move relatively slowly. Watch the dark, flat, rain-free base (of cumulus or cumulonimbus) near a shower to see if a bulge or tuft appears. If it extends down or becomes a smooth point, it is a funnel cloud which may indicate that a waterspout is imminent or occurring. In most cases, waterspouts are first seen by the spray ring at the water's surface and not by a fully-formed funnel cloud.



Waterspout sightings 1957-2010.

When waterspouts accompany severe storms, they can be just as dangerous as tornadoes over land. These may have a diameter more than 100 m and winds more than 100 kt. They can also be long-lived. Such tornadoes should be avoided at all costs.

Waterspouts occasionally occur with intense storms from May to September. Unlike waterspouts with non-severe storms, they may be wider, more wedge-shaped, and will extend from a very low, dark, cloud under a well-developed, large, fast-moving thunderstorm. Sometimes they are partly obscured by rain. They will occur in late-afternoon to early evening and most often near shore. The tornado usually forms over land and is carried over water when the storm moves offshore. Most severe storms are weakened by passing over the colder waters of the Great Lakes, greatly reducing tornado potential over the water. However, in a storm situation on a warm day, anything that looks remotely like a funnel cloud is a great cause for concern. At the very least, such a storm can also have large hail, intense lightning, and violent squalls with it.

Intense lows in spring and fall

Every boating season there are a handful of big blows that inflict wind damage, cause shoreline flooding, and pose a particular hazard to anyone who might have ventured out on the water. These intense lows can occur in April-May and again after late September. Both spring and fall examples are similar in structure and origin, coming up from the southwest and crossing the middle of the Great Lakes as they deepen rapidly. The result is a very tight pressure gradient and bank of very strong winds. Gale and storm warnings are often issued but the system's exact track and strength can change rapidly, making forecasting difficult at best. The sudden, sharp increases in wind speed and waves can make boating conditions dangerous.

The spring lows have their greatest impact over the Lower Lakes. The low centre often passes over Lake Huron, dragging a front and sharp windshift line to its south. The front may carry a strong squall line with it. Earlier rains and thick overcast break suddenly as strong southwest

"Don't take the lakes for granted."

Although most days during the recreational boating season present pleasure and relaxation to boaters of all kinds, wind, weather and waves can join forces to stir up trouble. When the elements have raged, many lives have been lost, and no boater should venture out without due respect for the numbing cold of our inland seas, or the sudden fury of a Great Lakes storm. As songwriter Stan Rogers wrote in his song "White Squall":

> *"But I told that kid a hundred times, "Don't take the lakes for granted.*
> *They go from a calm to a hundred knots so fast they seem enchanted.'*
> *But tonight some red-eyed Wiarton girl lies staring at the wall,*
> *And her lover's gone into a white squall."*

A few accounts of boating disasters (see *Hoisting the Basket*, next page) may serve us well, reminding us how small we, and our boats, are in the face of the churning and icy waters of our inland seas. As one Great Lakes sailor put it: "As a wave that could sink the Edmund Fitzgerald would certainly sink any boat that I've ever seen on the lakes." – John Angus.

winds set in for several hours. The band of strongest winds is accompanied by mild, dry air and a few cumulus or stratocumulus patches racing across the sky. This situation is aggravated by the shallowness of Lake Erie, where rising water levels can cause flooding at the eastern end.

The fall lows are more violent over the Upper Lakes. They are similar in all respects mentioned except that now a large surge of arctic air swings in behind the briefly milder phase. Southwest winds may be quite strong as well, but the west and northwest components (initially over Lake Superior, later over Huron and Georgian Bay) are the most dangerous. Not only are these winds passing over large stretches of water, but the air has become very unstable (the water is still warm), resulting in extremely gusty, erratic wind conditions. The waves respond in kind, and many marine tragedies attest to nature's merciless power at this time of year.

Hurricanes

The term "hurricane" was used until a few decades ago to refer to any major wind event. Today, it is reserved for the small but intense lows that occasionally form in the tropical Atlantic during late-summer and fall each year. Only rarely do these systems reach the lower Great Lakes (the most famous being hurricane Hazel in October, 1954), bringing heavy rains and several hours of gale or storm-force winds. True hurricanes are rare and limited in size, but sometimes the most intense lows of late-fall carry hurricane-force winds with them.

Hoisting the basket

Shipwrecks were so frequent along the shores of Lake Huron in the 19th and early 20th century that the government erected a storm signal station at the Port of Southampton and eventually heeded repeated demands for a first-class life boat... [because] of the frequent accidents occurring to vessels on our coast.

The storm signal station consisted of two wicker baskets, one cylindrical and one cone-shaped – which were hoisted to the top of a tall pole on Signal Hill.

Although the original signals are now in the Bruce County Museum and Archives, the Southampton Propeller Club has created replicas which can be seen atop a tall cedar post.

The following is just a small sampling of boating disaster reports on the Huron shores.

"Melancholy accident: Three Men, A Woman And A Child Drowned- ... by the capsizing of the sailboat North Star off the mouth of the Sauble River. It appears that the wind, which had been blowing fresh from the northwest, suddenly veered round to the west, and while attempting to beach the boat she was upset."

- *Hamilton Semi-Weekly Spectator & Journal of Commerce,* May 25, 1859.

"The lake was lashed into a perfect sheet of foam, and many a brave tar glanced from the deck of his vessel to the dreaded coastline with forebodings of evil which were soon to be realized in all their horror..." – *Huron Signal,* October 11, 1864.

"On Friday, November 2, an accident occurred near here by which a boy named Andrew Granville, aged 14 years, lost his life. In the company of his older brother, named George, he had gone out to look after some fishing nets. A squall upset their boat... When rescued, the deceased was lashed to the boat, having been placed in that position when the boat first capsized, but notwithstanding the efforts made for his safety, the exposure was to much for one so young…" – *Echo,* November 16, 1883.

"On Saturday morning, three fishermen … were caught in a fierce southeast gale that suddenly sprang up and were blown before the gale out into Lake Huron…" – *Times,* August 24, 1905.

"The steamer King Edward went on the rocky shoal just off Southampton on Saturday morning. A hole was stove in the ship's side, and she was abandoned by the crew. Unless taken off soon she will soon go to pieces in the fall storms. The accident is reported to be due to getting out of the channel during thick fog." – *Paisley Advocate,* September 10, 1908.

Hazards from winter conditions

Although this guide is directed mainly at conditions during the recreational boating season, windsurfers, some small craft operators and many commercial mariners will find themselves confronting winter conditions if they are out on the lakes in November and December. Those looking for challenging winds may even look forward to conditions in the late fall and early winter, when winds can be strong and gusty over water. Just make sure you are well-prepared and alert to the risk of hypothermia that cold water presents. (See page 87.)

Vessels that are on the lakes this late may encounter a risk of icing from freezing rain, freezing spray and steam fog.

Icing

Icing, the coating of all or part of a boat with ice, may have a significant impact on the vessel's safe operation. Not only can it make moving around on board exhausting and treacherous, it increases the vessel's weight and draft, and can be severe enough to change its centre of gravity. When a heavy coating of ice is uneven it can cause listing. Even if your vessel has a de-icing device there may be ice build-up on some high and exposed areas, so it is always wise to avoid conditions that cause severe icing.

Freezing spray is responsible for the most serious icing. The factors that contribute to it are:

- air temperatures lower than –3ºC
- winds greater than 20 kts: the stronger the wind, the more the spray (i.e. icing)
- water temperature lower than 5ºC, with little ice on the water
- waves high enough (2 m or more) to produce significant amounts of spray when they pound against the vessel
- vessel: the size of a vessel will affect the amount of freezing spray that is produced. The hull design is also a factor as some designs create more spray than others. Rigging or machinery on deck may also offer traps that accumulate spray

- speed and direction of movement: a vessel moving slowly or away from the wind will suffer far less from icing than will a boat heading quickly into the wind and waves
- a Freezing Spray Warning is issued when moderate to heavy freezing spray (icing rate 0.7-2 cm/hr or more) is expected.

Freezing rain also presents a risk of icing, and makes it difficult to operate your boat. Listen to the forecast before you go out. If a warm front is approaching, and there are strong easterly winds combined with temperatures a few degrees below 0ºC, you may encounter freezing rain.

Steam fog (see photo, above right) may also result in vessel icing, but will only deposit a relatively thin coating of ice as the supercooled water droplets suspended in the fog freeze on contact with a vessel. It will not significantly affect the safety of the boat, but may nevertheless prove inconvenient and risky for people moving around on deck.

Snowsqualls

A distinct characteristic of late fall and winter in the Great Lakes region is the presence of snowsqualls. When cold arctic air passes over the open waters, it becomes very unstable and large cumulus clouds form. These are like summer clouds except that now they cool rapidly and release large quantities of snow in snow flurries and snowsqualls. They are most intense with moderate winds, a long fetch, and a large difference between water and air temperatures. Most of the snow falls inland but the waters are also affected, especially when air temperatures are well below freezing and the air has passed over a long stretch of water. Sharp, localized reductions in visibility are common and the unstable air causes erratic, gusty winds.

A narrow line of Cumulus clouds and showers forms in the wind flowing off the Great Lakes. These intense disturbances often begin over water and often extend great distances over land.

Snowsquall outbreaks usually occur in the wake of cold fronts when a steady stream of arctic air persists over a region and high pressure doesn't immediately move in to weaken the flow. With west southwest winds, areas such as eastern Lake Erie and the Bruce Peninsula are significantly affected; with a northwest wind, southeastern parts of Georgian Bay and Lake Huron are most affected. The clouds tend to line up with the wind in long, parallel bands that remain stationary and shift slowly. While some locations under these streamers are being buffeted by heavy snow and gusty winds, adjacent areas only a few kilometres away may be enjoying fair weather.

Marine emergencies

Do you know what to do in the event of an emergency, and have you made sure that everyone else on your boat knows too? When you run into trouble, there is no time to start thinking about it.

Canada has a significant number of boating accidents. Why? Largely because personal flotation devices (PFDs) often are not used; and this, combined with cold water conditions and the use of alcohol or drugs while boating, can lead to disaster.

Make sure you don't become another statistic – follow these simple rules:

Before You Go

- Check the forecast for your route and revise or postpone your plans if threatening conditions are likely.
- Make sure everyone on board is wearing a Personal Flotation Device (PFD), preferably one with a hood, which will decrease the rate of heat loss.
- Do not use alcohol or drugs immediately before or while boating. They will slow your reactions, increase the risk of hypothermia if you capsize, and cloud your judgment when you need it most. Alcohol is involved in at least half of all boating fatalities.
- Go through emergency procedures with everyone on board.
- Know the temperature of the water. Everyone on board should have a healthy respect for the danger cold water presents. Keep an eye on developing weather and be prepared to turn back if a change in the weather threatens your safety.

Personal flotation devices

"Usually in a drowning situation on Lake Ontario, they go to the bottom. They will remain there indefinitely. ...Without a flotation device, it's really a waste of time searching." – Marine Captain Adrian Lewickie.

Tip: Equip your boat with PFD's that are brightly coloured or fitted with fluorescent tape. Not only do you want to be able to remain afloat – you want to be easy to spot when you need help!

You're in Cold Water!

Hypothermia is a drop in your body temperature to below its normal level because of being very cold for a long time. Hypothermia affects a person's control over their muscles and thinking. Someone who is exposed to cold water and becoming hypothermic might:

- shiver, use slurred speech and become semi-conscious;
- have a weak, irregular or no pulse;
- breathe slowly;
- lose control of body movements;
- behave in ways that don't make sense;
- act confused and/or sleepy;
- stop breathing; and
- become unconscious.

If you end up in the water, do everything you can to save your energy and body heat. Swim only if you can join others or reach safety. Do not swim to keep warm.

You may survive longer in cold water if you:

- wear a Canadian-approved lifejacket so that you will not lose valuable energy trying to keep your head above water.
- climb onto a nearby floating object to get as much of your body out of or above the water as possible.
- cross your arms tightly against your chest and draw your knees up close to them to help you keep your body heat.
- huddle with others with chests close together, arms around mid to lower back, and legs intertwined.

If you have warning that your boat may sink, protect yourself from the cold by wearing multiple light layers of dry clothing and a water or windproof outer layer under a lifejacket. Extra protection from hypothermia includes:

- floater or survival suits (full nose-to-toes lifejackets);
- anti-exposure worksuits (lifejacket with a thermal protection rating);
- dry suits (to be used with a lifejacket and a thermal liner);
- wet suits (to be used with a lifejacket – trap and heat water against the body); and
- immersion suits (to be used in extreme conditions when abandoning a vessel).

Treatment for moderate to severe hypothermia

This is a serious medical emergency requiring proper handling and treatment and in severe cases, immediate transport to a medical facility. There are some specific things you can do to help stabilize the individual prior to the arrival of paramedics.

Great care must be taken in handling a moderate or severely hypothermic person. Extraction from the water must be as gentle as possible to avoid precipitating ventricular fibrillation. Arms, hands, feet and legs should not be rubbed or manipulated. The person should be placed n a horizontal position and wet clothing should be gently removed and the body insulated as best as possible using dry blankets, clothing or other protective materials. If shelter is available, keep the person protected from the elements and insulated from the cold ground or snow using sleeping bags, clothing, back packs or even evergreen boughs.

If vital signs are present, the person should be rewarmed as previously described but not allowed to sit or stand until rewarmed. Under no circumstances should the person be placed in a warm shower or bath, no oral fluids or food should be given and no attempts shoud be made to rewarm with exercise, including walking.

In any hypothermic individual, core body temperature continues to decrease after rescue. It is called 'afterdrop' and may last many hours in a moderate to severely hypothermic person when no shivering is present and metabolic heat production may be only 50 percent of normal. Even gradual warming of the heart will help avoid cardiac arrest and ventricular fibrillation.

Protect your boating environment!

It is against the law to dump garbage or discharge pollutants into our waters. If any of us are to continue enjoying boating, we all need to take responsibility for keeping them environmentally safe.

Here are a few tips to help you keep your boat and your boating clean:

- Stay clean with plain water and wax. Before launching, clean your boat thoroughly on land and apply a good coat of boat wax. This will enable you to slosh off most dirt with plain water, avoiding the use of other cleaning agents.
- Mop up spills right away, before they set.
- Avoid harsh cleaners, soaps and detergents. There are many safer, easily available cleaners. Look for the Environment Choice[M] Logo, or use household substances like olive oil, vinegar and baking soda. (*Get The Enviro Boater Guide,* from the Canadian Power and Sail Squadrons, and *Protecting the Aquatic Environment: A Boater's Guide,* from The Department of Fisheries and Oceans and the Canadian Coast Guard).
- Avoid producing grey water on board. Minimize or eliminate the use of soaps and detergents.
- Report any releases of "black water" to authorities. They can result in serious bacterial infection. If you have a marine toilet, make sure it meets all environmental standards.
- Fill up with care. Have several cloths at hand for immediate mop up of any fuel spill. If possible, use a portable tank so that you can fill up away from the water.
- Don't let your bilge residues get into the water. Keep on top of spills and leaks and have bilge pillows on hand.
- And don't forget to reduce, reuse and recycle. Avoid accidental pollution by not taking items such as Styrofoam cups and the plastic rings from pop cans on board. The best rule of thumb is: what goes out on the boat must come back on the boat.
- Leave the water cleaner than you found it.

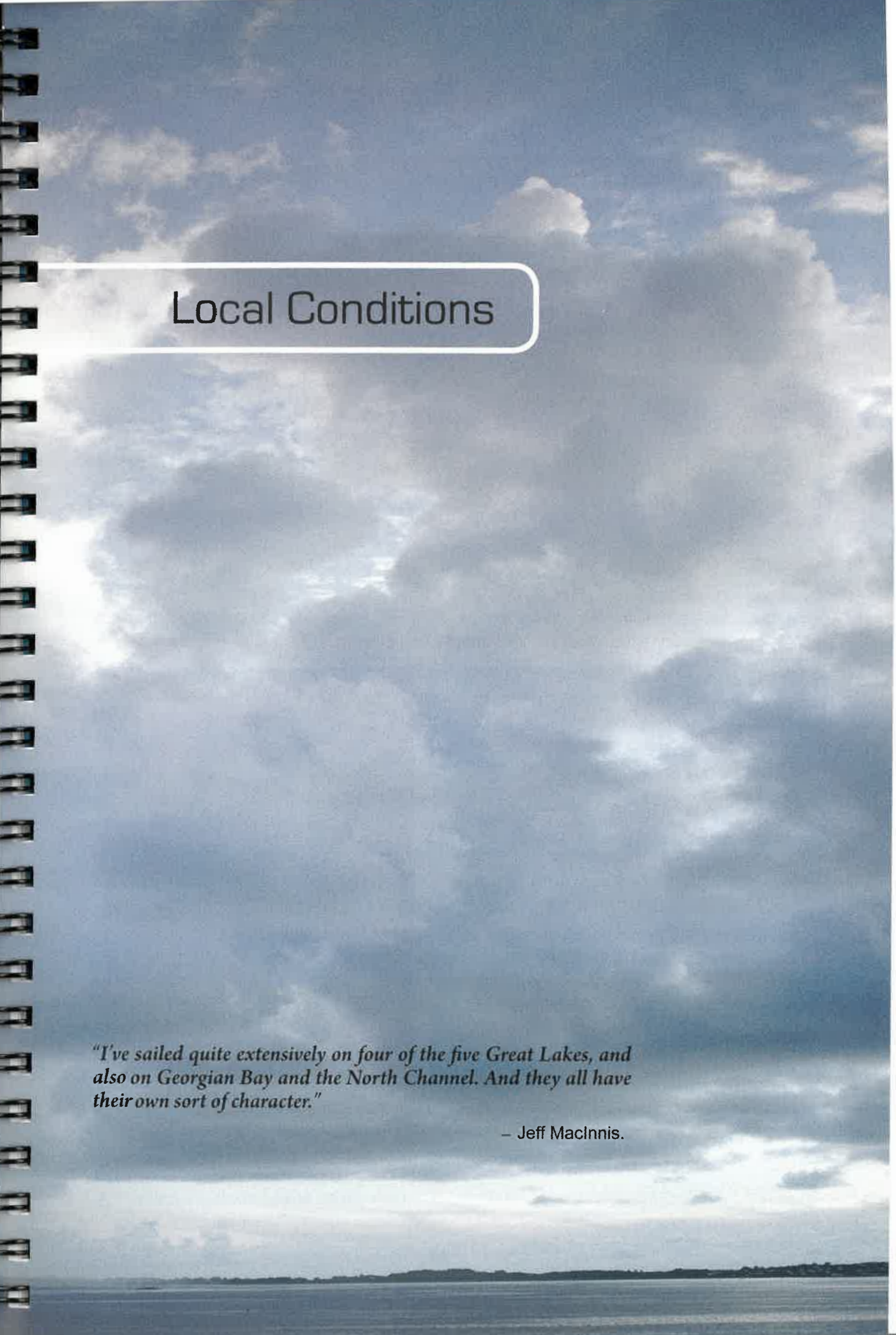
Zebra mussels

These barnacle-like hitch-hikers are a multibillion dollar threat to North America's industrial, agricultural, and municipal water supplies, and a nuisance for shipping and fishing. Make sure you don't give them a lift to new waters!

What do they look like? Small (up to 5 cm long, but usually closer 2 to 2.5 cm) yellowish or brownish D-shaped shells, like a clam with dark and light stripes, usually in clusters attached to solid objects.

If you think you may be in infested waters, before you enter other waters:

- Drain all the water from your boat, bait-well and engine-cooling system.
- Inspect all equipment for signs of infestation.
- Scrape off grainy surfaces (the graininess may be young mussels).
- Wash your boat with water hotter than 40°C.
- Dry equipment in the hot sun for three or more days, then scrape off any remaining zebra mussels.
- Report all suspected growths of zebra mussels, or other environmental incidents to the Canadian Coast Guard at **1-800-265-0237.**



Local Conditions

"I've sailed quite extensively on four of the five Great Lakes, and also on Georgian Bay and the North Channel. And they all have their own sort of character."

– Jeff MacInnis.

USING THIS GUIDE FOR LOCAL CONDITIONS

Whereas preceding parts of this guide have laid out the general principles of marine weather systems, this section deals with the peculiarities of specific locations around the Great Lakes, along with four other lakes in the Great Lakes region. To avoid repetition, the information is presented in a telescoping fashion. First, each lake is introduced with a discussion of its general characteristics. Then, more detailed information is presented for each of thirteen "local conditions" areas into which the lakes have been divided. (see local conditions areas on the map, on the next page). Finally, in each of these local areas there is a port-by-port discussion which gives specifics about each harbour and the marine conditions nearby.

Each area is accompanied by a map which provides a visual quick reference to local conditions, with colour-coded symbols to represent significant factors to consider. (See Symbol Key, opposite page). Conditions shown on the map are indicated in the text with colour coded highlights (corresponding to the colours in the key).

In *Working together*, which follows this section, starting on page 127, we provide details on what kinds of information you can get to brief yourself on weather and water conditions, from Environment Canada, the Canadian Coast Guard and other sources.

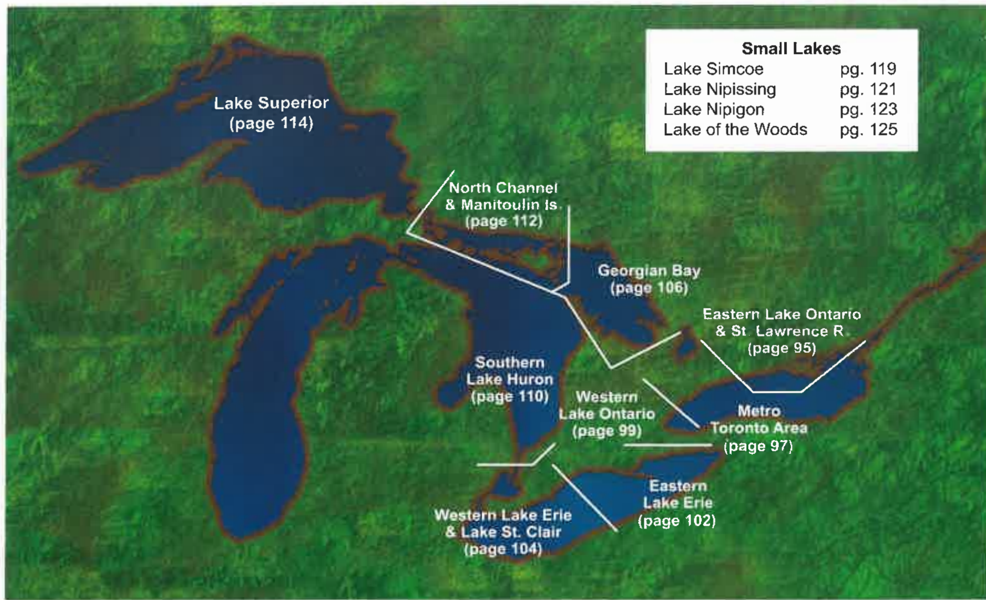
Wind, weather and waves has taken you on a tour of the elements as they affect boating in the Great Lakes region, and by now you will be familiar with the importance of recognizing local effects when interpreting the forecast.

This is your chance to try your skills at fine-tuning your weather senses. Get to know what you might expect under varying weather conditions in your area. And, if you find there are significant local effects that are not mentioned in this guide (and there are sure to be some!) please let us know by contacting us via one of the methods indicated at the back of the book. Good luck and safe boating!

Weatheradio frequencies

Wherever you are, use Weatheradio to monitor weather changes. Check all frequencies to find the nearest broadcast.

162.400, 162.425, 162.450, 162.475, 162.500, 162.525,162.550 MHz



Local conditions area.

Symbol Key

- Sailing, windsurfing
- Recreational boating
- Commercial traffic
- Thunderstorms
- Waterspouts
- Heavy Seas
- SW Heavy seas with winds from
- Strong current
- Cross seas
- Gusty winds
- Strong winds

Note: when larger, symbols indicate features that apply to the entire region.

Local weather effects

Your local conditions will be influenced by several weather factors which are true for all areas to one degree or another. For example, cloudiness and storms will be reduced if they come in over a large stretch of water. By comparison, there will be new clouds and possible storms downwind over land, often along the lake-breeze front. A persistent offshore flow will cause upwelling of colder water, increasing the likelihood of fog there. And, of course, the alignment of topography, long stretches of water and the day's wind flow will cause certain places to have much higher winds and waves than you would have expected from your nearshore experience.

LAKE ONTARIO

"We must sail sometimes with the wind and sometimes against it – but we must sail, not drift, nor lie at anchor."

– Oliver Wendell Holmes.

"Where vast Ontario rolls her brineless tides… "

– Erasmus Darwin, 1791.

Introduction

Ketch with clear sailing.

Although Lake Ontario is the smallest (surface area of 18,960 km^2) of the Great Lakes, boating activity in Canadian waters is heavier than on the other lakes. Not only are there several sizable population centres on its shores, heavy industrialization adds to traffic and pollution problems.

Recreational boats of every imaginable type – from sailboard to schooner, from canoe to yacht – compete with commercial traffic (lakers and ocean-going ships), ferries and even military vessels. The diversity and numbers of boats on the lake can cause problems, and boating collisions are a particular hazard on Lake Ontario. Care must be taken when visibility is poor: at night, or in fog, smog, haze or rain.

The most highly variable weather on Lake Ontario occurs in the spring and fall. In spring and early summer, alternating warm and cool air masses move through quickly, causing cloudiness and frequent thunderstorms. Make sure that you listen for marine and small craft forecasts and warnings, and never assume that a cloudless morning means clear sailing later in the day. Check the forecast and keep your eye on the sky.

In summer, Lake Ontario's weather presents fewer hazards to the boater than might be encountered on Lake Erie or Lake Huron. You may find yourself complaining more frequently about calm than stormy waters. However, don't get too nonchalant.

Waves on Lake Ontario are generally only up to 1 m high, but in rare cases they may exceed 5 m. Lake Ontario has some of the deepest waters in the Great Lakes. Its average depth is 86 m – second only to Lake Superior. Although the surface may be warm in the heat of summer, upwelling of water from the frigid depths does occur, particularly along the north shore, from Burlington to Oshawa, after two or three days of west to northwest winds.

Tropical air masses moving up from the Gulf of Mexico are a major influence on summer weather, and occasionally a temperature inversion occurs (especially around the Golden Horseshoe). The cooler air near the lake surface is trapped under a layer of warmer Gulf air above, allowing pollutants and humidity to build up, and creating calm but very unpleasant, muggy conditions.

The effects of lake breezes are noteworthy on Lake Ontario, particularly in the Greater Toronto Area where the difference in temperatures over the warmer land and cooler water are amplified by the miles of concrete (buildings and highways) along the lakeshore. The resulting lake breeze is enhanced by channelling (and with east northeast winds, by convergence), making winds between Mississauga and Oshawa particularly brisk and pleasant for sailing.

Lake Ontario does not freeze over completely, but should you be out as late as December (before there is any ice to dampen the effect of icing from spray), be alert to the possibility of icing with strong winds, high waves and even thick fog.

Lake Ontario local conditions are divided into three regions – East (from Brockville to Colborne), the Greater Toronto Area (from Cobourg to Toronto), and West (from Clarkson to Niagara-on-the-Lake).

Conditions on Eastern Lake Ontario and the St. Lawrence River

(from Brockville to Colborne)

General characteristics: Wind and sea conditions can be very complex in the extreme eastern end, due to the lake breeze effect, shoaling, currents and various nearshore effects associated with the many islands and straits. However, the channelling of winds to either southwest or northeast and funnelling by the St. Lawrence River Valley are by far the most obvious wind features at this end of the lake. Lake breezes are common for much of the summer. There can be heavy fog in spring, and there are occasional thunderstorms during the summer. Bays in the east end may experience wave set-up of up to 1 m with strong southwest winds. The inshore recreational boating route for the north shore of Lake Ontario runs from Belleville to Brighton, and boating traffic is heavy and mixed (recreational, commercial, military and international traffic) from Prince Edward Country up into the St. Lawrence River.

Sun setting behind freighter.

1. **Brockville to Gananoque:** This is a busy area, and choppy seas make the well-protected harbour at Gananoque welcome. However, with southwest or northeast winds there may be steep seas east of Gananoque to the narrows due to funnelling along the St. Lawrence

River (this is worse with northeast winds). The high islands produce corner effects, with gusty lee eddies. Currents can be 2-3 kts southwest of Brockville and they are strong south of Gananoque harbour, too.

2. **Kingston Harbour and approaches:** There is heavy mixed boating in this area, including international traffic. There is excellent sailing and windsurfing due to consistent winds of moderate strength. Boaters may enjoy the pronounced onshore wind here, which is due to the funnelling of winds through the lower gap between Amherst and Wolfe Islands. These breezes are southerly at Kingston and southwesterly and slightly stronger in the channel between Wolfe Island and the mainland. Even moderate winds from the south to southwest build 1-2 m waves offshore due to the long fetch. Shoals, corner effects (islands) and funnelling at the lower gap can cause choppy seas at Kingston.

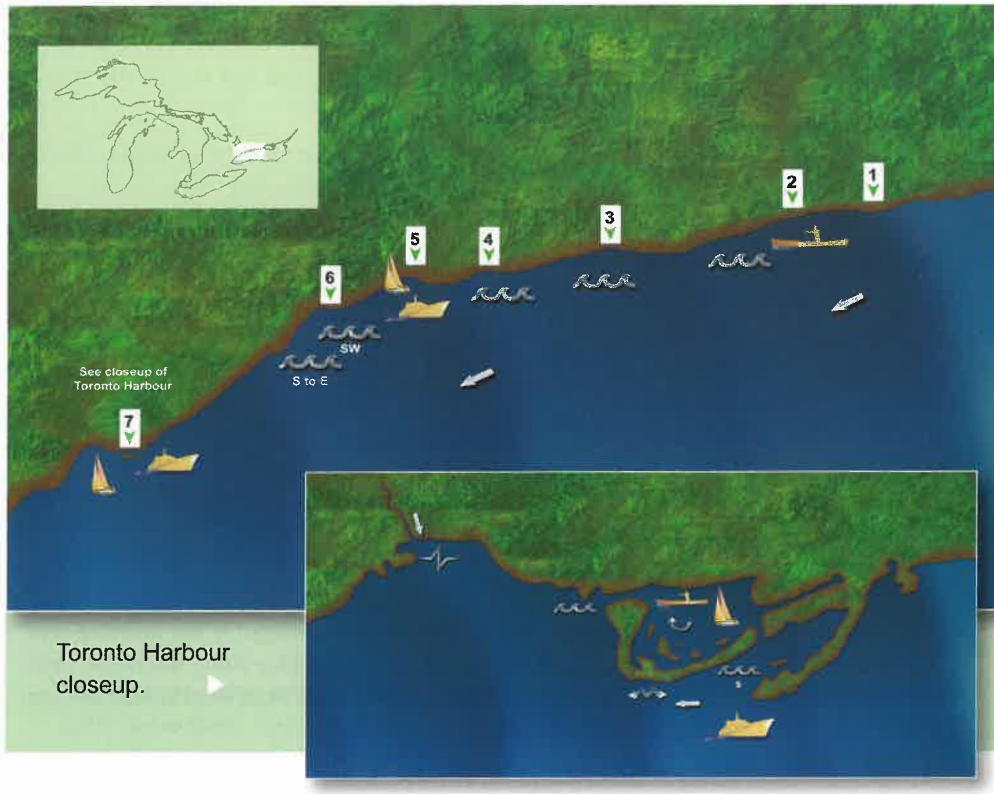
3. **Amherst Island to Prince Edward Bay:** Protected anchorage is available at Prince Edward Bay, which may be a welcome relief because shoaling combines with high waves (due to a long fetch) from Prince Edward Point west to Presqu'ile, producing heavy breaking seas. These conditions, which occur with strong winds from the west through southwest, can make this a hazardous area. Prevailing winds are southwest. With northeast or southwest winds, wind driven currents of ½ kt can cause heavy seas in the North Channel. At the west end of Long Reach there may be heavy choppy waters because the north to south current interacts with waves built by funnelling southwest winds. This region is mainly ice-covered in winter, which is unusual for Lake Ontario.

4. **Belleville to Trenton (Bay of Quinte):** This area is used mainly by daysailors and windsurfers. The shallow channel of water results in channelling of winds to the southwest or northeast, which may produce choppy waves of up to 1 m at the end of the fetch. Currents run west to east.
5. **Brighton:** This harbour is used for recreational boating, but is too shallow for large vessels. Shallow waters cause shoaling and choppy seas with southeast winds.
6. **Colborne – Ogden Point:** This commercial harbour is very exposed to southwest seas. There is a very strong current running from west to east and channelling when the winds are southwest.

Conditions from Cobourg to Metropolitan Toronto

General characteristics: This area gets heavy recreational use and great diversity in boat traffic. Southeasterly winds over the lake are channelled to easterly along the north shore. The resulting brisk winds make for pleasant sailing. Predominant nearshore currents are east to west but become variable just west of Toronto. Once in a while summer inversions create very calm and muggy conditions.

1. **Cobourg:** This port is difficult to enter with winds east through south to west – with 1 m waves a vessel with 2-3 m draft can hit bottom. There is shoaling 1½ km offshore and silting in the port. There can be strong winds due to channelling along shoreline, and these may enhance the lake breeze effect. A strong current runs from west to east 2-8 km offshore.
2. **Port Hope:** This recreational harbour has a sandbar at its entrance, and there can be shoaling and rough waters there. South to southeast winds create a danger of bottoming out. The wind induced currents usually run from east to west.
3. **Newcastle:** This port is exposed to the south and there are heavy seas with southerly winds. Shoaling 1-2 km offshore can cause choppy seas. There are wind induced currents – usually east to west.
4. **Port Darlington:** This very shallow harbour (less than 2 m) gets heavy wave build-up at its entrance and is limited to small recreational use. It is very exposed to the south and there are strong offshore currents from the west.
5. **Oshawa:** Traffic here is both commercial (outer harbour) and recreational (inner harbour). Winds from the southeast through south to southwest make entry difficult, and the prevailing winds are southwest. Wind set-up may raise water levels 30 cm, making conditions in the harbour more difficult.
6. **Whitby:** Winds from south through east provide a long fetch, with waves running right up the harbour and reflecting off the inner wall. There are strong currents 1½ km offshore.
7. **Toronto Harbour and approaches:** This harbour gets heavy recreational and mixed use. From April to December commercial vessels use eastern and western gaps. The lake breeze is enhanced by the heat of this large urban area – winds near Toronto Island are often easterly during summer because of the lake breeze and channelling.



Toronto Harbour closeup.

Approaching the harbour from the east, there can be confused seas due to shoaling 1½ km offshore from the Eastern Gap to Frenchman's Bay, and entry may be difficult with southerlies. Waters near the Scarborough Bluffs are shielded from winds when they are northerly (wind shadow). The Leslie Street Spit shelters the waters of Toronto Harbour has variable winds with some gustiness due to the city heat and tall buildings.

The western approach to the inner harbour can have confused seas due to the reflection of waves off sea walls, but inside the harbour passage is calm. There is noteworthy current along the south side of Toronto Island. Its direction varies and it is surprisingly strong. Humber Bay is sheltered with southeasterlies, but southwesterlies can cause waves to reflect off the seas walls. There is probably wave/current interaction at the mouths of the Humber and Rouge Rivers, and some funnelling of winds down the Humber Valley. Summer inversions can make conditions muggy and uncomfortable from time to time.

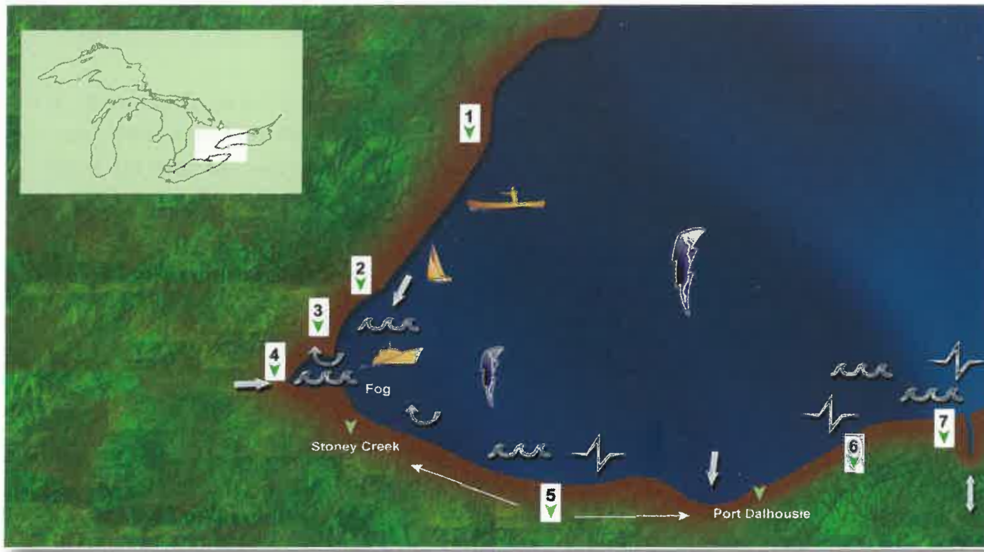
Conditions on Western Lake Ontario

(from Clarkson to Niagara-on-the Lake)

General characteristics: With west winds there is channelling along the south shore of Lake Ontario. The Niagara Escarpment produces local effects due to high land from Burlington to Beamsville, and thunderstorms often for over the escarpment and move out over the water.

1. **Clarkson:** Channelling along the shore enhances the lake breeze here. Currents are variable – they are reported to run from west to east near the shore a significant portion of the time (opposite to the officially recorded direction).
2. **Bronte Harbour:** This is a recreational harbour, with a strong east to west current 1½ km offshore.
3. **Burlington (piers):** There is heavy commercial and industrial traffic in this area. In the fall, westerlies funnel down Hamilton Harbour from Dundas Valley, causing breaking waves and unpredictable swirls and eddies at the Canadian Centre for Inland Waters breakwater and the west side of the Burlington Piers. There is a 1-2 kt current in the canal, and there can be cross seas at the piers with strong easterlies. This is because the long fetch allows for heavy waves, which then reflect off the piers and interact with the offshore current. With northeast to east northeast winds, convergence strengthens wind and wave conditions. Watch for submerged pilings off the beach southeast of the Burlington Canal. Summer inversions can cause muggy unpleasant conditions, especially given the heavy industry in this area.
4. **Hamilton Harbour:** Heavy industry predominates in this harbour, with some recreational boating on the north shore. Funnelling down the Dundas Valley increases wind speeds with both east and west winds – by roughly 50% relative to surrounding areas. Thunderstorms also tend to follow this valley to the harbour. With southwest to west winds the harbour can be rough while the lake is calm – lee effects (cliff effect) from the escarpment cause locally gusty and/or calm patches. Strong northeast winds prevail in spring and early summer and then again in fall. This is due to the channelling of winds into the harbour, combined with the lake breeze effect. Frequent summer inversions trap heavy pollution and haze, resulting in visibilities of less than 10 km; and with northeast winds in spring, heavy fog can be trapped in the harbour by a capping inversion and the escarpment.

Gale-force winds rake the water surface as skies begin to clear behind an intense spring low.



5. **Stoney Creek to Port Dalhousie:** From Hamilton to Beamsville cliff effects (from the escarpment) can cause local gusty winds and confused seas. Currents run from west to east and can produce wave/current interaction. There is shoaling at the entrance to Grimsby Beach. With northwest winds channelling cause convergence along the south shore of the lake and increases wind speeds. Brisk onshore winds are common from Vineland to Port Dalhousie. Northeast to north winds can bring heavy seas (long fetch). Currents at the Port Dalhousie pier entrance are generally 1 kt, but when the sluice gates are opened they can get as high as 3 kts. Thunderstorms can cause flooding of the west pier. Port Dalhousie is the only protected port between Hamilton and Niagara, but it may be difficult to enter with strong north to east winds (heavy seas).
6. **Port Weller:** There can be heavy seas at the pier with east or west winds. With strong winds southwest through northwest, there are heavy waves in the bay to the west of the piers, but it is well-protected with light winds (up to 12 kts) from these directions. Strong wind-driven currents interact with the flow from the canal to produce confused seas. Dumping from the locks makes berthing difficult in the reach.
7. **Niagara-on-the-Lake:** Wave/current interaction can be dangerous in this area, and shoaling in the bay worsens it. There is also some funnelling along the river. A river current enters Lake Ontario flowing to the northwest, but westerly winds divert it eastward along the south shore. Easterlies produce riptides and a clockwise gyre east of the river mouth and establish cross-lake flow. The result can make for very difficult sailing. There can be heavy seas (locally called "green mountains of sea"), which are especially treacherous with northerly winds. The marina provides safe shelter once you arrive.

LAKE ERIE

"In September 1861, I was lying under Long Point when a waterspout bursted near us, and there was such a commotion in the water that my vessel walked away with her anchor."

– Charles Gale, Marine Record.

"The wind and waves come up so quickly on Lake Erie that you can go from dead calm one minute to ten foot waves within ten minutes."

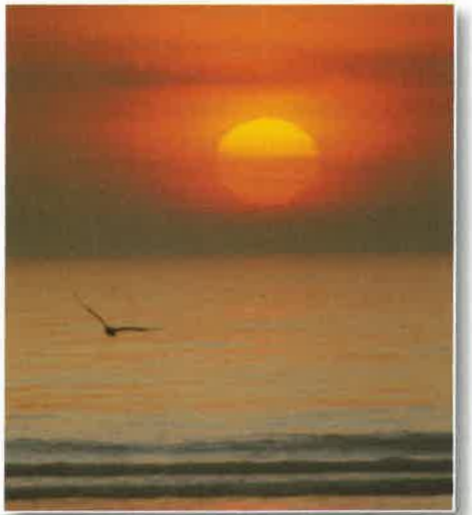
– Steven Donker.

"Erie is kind of our worst case scenario for weather – everything blows up much faster here. Ontario, being much deeper, tends to be much calmer. We'll have three to four metre waves in Lake Erie whereas in Lake Ontario they'll only be around one. For small craft that makes a big difference."

– Woman at weather station.

Introduction

Boating on Lake Erie is not for the faint of heart. It is prone to sudden and violent weather changes (for instance, squalls) which make it one of the most dangerous lakes in the Great Lakes system. Most of the time the weather is fair and boating conditions are pleasant, but thunderstorms can develop quickly, whipping up large waves on this shallow lake.



Gull sailing on the currents.

Although it is larger in area than Lake Ontario, Erie is by far the shallowest lake (average depth, 19 m). The gently rising land on either side of Lake Erie routinely channels winds along its east-northeast to west-southwest axis. These prevailing southwesterlies combine with sudden windshifts to stir up steep waves and cross seas. Funnelling causes winds to be stronger in the east of the lake than they are in the west, but there are also short steep waves in the western basin (west of Pt. Pelee) due to the shallowness of the waters and wave/current interaction. The prevailing year-round wind speed is 10-15 kts, but it exceeds 20 kts 20% of the time in summer and more than half of the time in winter.

Even under normally benign weather regimes, there is usually some part of Lake Erie that produces hard to predict challenges for the boater.

To make matters worse, a good safe harbour is hard to come by on Lake Erie. With southwest winds many of the ports are under the influence of onshore wave conditions, and they are very difficult to enter with following seas. And although the western basin is more protected, it is extremely shallow, further complicating matters. With strong southeast winds, shoreline channelling produces wind driven currents set from east to west along the north shore which, combined with the shallow water and high waves, makes entering harbours difficult anywhere on the Canadian shoreline.

Water levels are affected by very large wind set-ups, followed by seiches. With southerly winds at 40 kts or more, the east end of the lake may experience a surge of over 1½ m. Combined with 3-4 m waves, these surges cause erosion to shorelines and damage to harbour facilities. Fortunately, there are usually less than 2 or 3 such events per year especially in recent years due to lower than average lake levels.

To add to the challenge of boating on Lake Erie, severe weather is more common than on the other lakes. There are 8-10 days of severe thunderstorms in the area each summer. Even as the hot stormy days of summer are replaced by cooler spells, you cannot take the weather on Lake Erie for granted. Waterspouts occur 4-6 days per year from late July through to October – especially in the warm western basin (west of Pt. Pelee). Never set out without checking the forecast and watching the skies. And know where your nearest safe anchorage is.

Early in the boating season – in late March and April – fog can be a problem, but the lake warms up quickly and there is little fog by June. Lake Erie gets less fog than any of the other Great Lakes. In the late fall freezing spray can be a serious problem as high winds and chaotic wave action coat your boat with ice. Occasionally lakers have to remove ice at Port Colborne to have enough beam and draft to pass through the Welland Canal.

Traffic on Lake Erie is mixed, including recreational boating of all types, fishing vessels (Long Point Bay area and the east and west sides of Pelee), and commercial traffic (lakers, gas drilling rigs and other ships).

For the description of local conditions Lake Erie has been divided into two areas – East (from Fort Erie to Port Stanley) and West (from Port Stanley to Amherstburg), including Lake St. Clair.

Conditions on Eastern Lake Erie

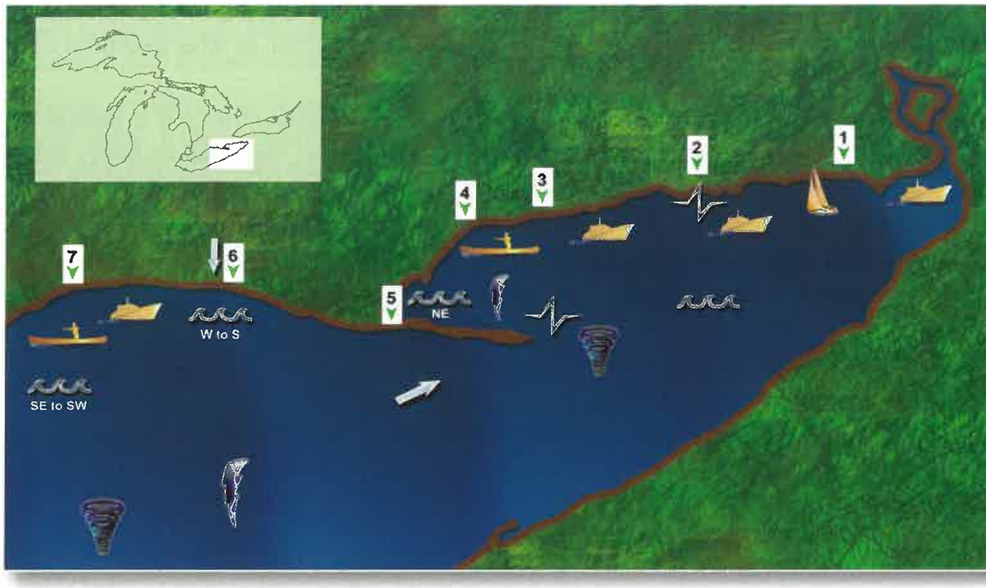
General characteristics: The prevailing southwesterlies on Lake Erie are strengthened by funnelling at the east end, causing high waves and sometimes choppy seas. Wind set-up can cause dramatic rises in water level at this end of the lake – up to 2 m in extreme cases. For the most part, summer skies are clear and weather is pleasant in eastern Lake Erie, but windshifts and thunderstorm activity can make boating hazardous in short order, so keep a weather eye open!

1. **Port Colborne:** There is heavy commercial traffic in this port, including vessels going through the Welland Canal. There is good shelter behind the breakwall, but cross seas

cause very rough waters outside the harbour entrance. Strong northeast winds can cause low waters followed by seiche oscillations, while strong winds from all other directions can cause high waves and difficult entry to the harbour.

2. **Port Maitland:** This port caters mainly to commercial and fishing traffic. It is difficult to enter because it is exposed to the prevailing southwest winds. There can be heavy seas with southwesterlies – beware of the reef at Gull Island. A river current during spring run-off may result in wave/current interaction.
3. **Nanticoke:** This is a commercial dock that is difficult to tie up at with anything but light southeast winds. Strong currents coming around Long Point can reverse and cause eddies and wave/current interaction.
4. **Port Dover:** This fishing and recreational harbour can be difficult to enter when there are southwest winds (often). However, the expanded outer harbour marina offers good protection once entered. High ground around the river channel/harbour causes funnelling with northerly winds and morning valley winds. There are counter/clockwise currents in Long Point Bay. There are frequent thunderstorms from June-August between Port Dover and Long Point Bay.
5. **Long Point and Inner Bay:** This area is protected from the south by the peninsula. With northeast winds, channelling causes high waves (2 m) with a strong alongshore current setting to southwest. There is also a strong counter-clockwise current around the shallow (7 fathom) hump in middle of bay – it can reach 5 kts during storms. There may be cross seas near the end of the point during heavy weather. Long Point is subject to frequent thunderstorms and is a favoured location for waterspouts.

Storm approaching on horizon.



6. **Port Bruce:** This harbour provides poor shelter – there is no protection from the west through south and it is unapproachable with strong south winds. Cliffs at the creek entrance cause funnelling with northerly winds. There is a long stretch without good shelter from Long Point to Port Bruce (Port Burwell is silted).
7. **Port Stanley:** There is commercial and recreational traffic in this port. There can be very short steep waves (shoaling and wave/current interaction) with winds southeast through southwest (southeast winds are worst). Currents are from the south, but they veer to the west as they approach shore.

Conditions on Western Lake Erie and Lake St. Clair

General Characteristics: The western basin of Lake Erie (from Pt. Pelee to Amherstburg) is shallow and warm. The water temperature there can exceed 24ºC – remarkably higher than the other lakes. Its shallowness makes it prone to choppy wave conditions as waves build up on shoals and refract around bends and points; and currents and waves interact to complicate matters. Thunderstorms and squalls are more frequent than elsewhere on the lake during the summer season, waterspouts occur throughout the southwestern basin in the late summer and fall. Seiche events can be as heavy as 1–2 m. Gale force southwesterlies can cause water levels to drop over 1.5 m, leaving some boats high and dry in extreme cases.

1. **Rondeau (Erieau):** This is a shallow harbour, difficult to enter with southerly winds. The channel into Rondeau Bay has strong currents with fluctuations in lake level. There is a strong current at Point Aux Pins.
2. **Wheatley:** Shoaling 5 km offshore causes waves to break with easterlies. Counter-clockwise currents combine with waves generated by northeast winds, creating high and breaking waves offshore.

Sunrise with cumulus clouds.

3. **Pelee Island (Scudder Harbour):** This is the best harbour on Lake Erie, with a sheltered entrance on the north side. Counter-clockwise currents combine with shoaling and refraction to create choppy wave conditions.
4. **Leamington and Kingsville:** Leamington harbour has recreational and ferry traffic. Kingsville harbour has ferry and fishing traffic. It is shallow, and grounding is possible with strong southwest winds. It is difficult to enter for docking with southeast winds. South to southeast winds are strengthened due to funnelling between Pt. Pelee and Pelee Island and shoreline convergence. These winds produce heavy and confused seas due to shoaling and wave/ current interaction.
5. **Amherstburg:** This very busy area has well protected wharves. Strong northerly winds funnel down the river. Waves and a river current of 1-2 kts produce heavy choppy seas with winds from the southwest through southeast, especially near shoals. Strong southwest winds can significantly lower water levels.
6. **Lake St. Clair:** Over most of this shallow lake traffic is recreational, but there can be heavy commercial traffic in the narrow shipping channel that runs up the centre. Smaller boats may encounter high waves from the wakes of these ships. Strong southerly winds may also build steep waves. Conditions are similar to those on western Lake Erie (winds produce choppy waters due to shallowness), with relatively frequent thunderstorms and waterspouts. There are frequent lake breezes. In the late fall and early winter, there are snowsqualls. See also the note on Smaller lakes, page 118.

LAKE HURON/GEORGIAN BAY

"We have some people who get caught in offshore breezes. You've got to be very careful. If you're a windsurfer and you get caught and the wind's blowing away from shore, your chances of getting back to shore if you get worn out are getting slimmer the further you go out there."

- Jamie Oakley, Canadian Coast Guard, Goderich.

"A grey and white cloud rose like a pillar, swelling with every stretch of altitude it cleared. Georgian Bay has its own special squalls, and this was a biggy."

- Dave Martin, in QAYAQ, Summer, 1996.

Introduction

Lake Huron is much larger (surface area of 59,600 km²) than Lakes Ontario and Erie, but not quite as deep (average depth of 60 m) as Ontario. There are many cottages along its shores and boating traffic, particularly in Georgian Bay, can be heavy.

Pointe au Baril.

Lake Huron offers great variety to the boater, from the vast open reaches of cold water to the protected beauty and challenging sailing of the 30,000 Islands. Conditions are generally pleasant in summer, with precipitation occurring roughly 5% of the daylight hours over the lake, and slightly more frequently in the North Channel. Visibilities are also good, dropping below 1 km only 5% of the time on Georgian Bay and a little more often on northern Lake Huron.

We have divided the lake into three distinct areas: from Sarnia to the Bruce Peninsula, the North Channel (including Manitoulin), and Georgian Bay. The characteristics of these three areas are sufficiently different to make it difficult to generalize about the whole of Lake Huron.

Conditions on Georgian Bay

General characteristics: Nearshore wind effects are of particular importance in Georgian Bay because of the many islands, channels and inlets, and the varying shoreline topography. Winds are also channelled down the bay on a broad scale, resulting in a predominant northwest wind direction. This produces convergence along the south shore (and high ground) from Meaford to Collingwood and, as a result, seas are very heavy in this area. This may be accompanied by a rise in the water level of ½ m and pronounced waves in harbours along the south shore.

Be particularly alert to corner effects and funneling as you travel through the 30,000 Islands. Its many shoals and islands produce complicated wave action. Strong southwest through northwest winds produce significant wind set-up in the channels along the eastern and northeastern shores of the bay. At the ends of these channels, set-ups have been reported to be as high as 2 m. And with strong northeast winds there can be increases in water level and violent wave action from Cabot Head to Collingwood.

Wind speeds within the 30,000 Islands often exceed open water speeds due to funnelling effects, and wind is channelled by the many islands. There are also many shoals, over which waves can build up steeply.

From Tobermory to Collingwood and within the Midland Channel you cannot see weather coming in from the west because of the high land in that direction. Unless you pay close attention you may be caught unaware by a thunderstorm. Waterspouts are also possible throughout Georgian Bay during the cold air outbreaks that occur from late July through to November and sometimes through early December.

Visibility problems sometimes occur due to haze that accompanies south winds, or with occasional dense fog in spring, when the warm moist air blows over the still cool waters of the bay.

Remember that even when waters are calm and warm in a small bay or inlet you may encounter much colder, rougher waters out in the open. Be prepared for heavy going.

There is heavy recreational traffic in Georgian Bay – from large cruisers to sailboards and waterskiers – and the many islands and channels make it especially important to know the waters and boating rules well.

1. **Tobermory:** This is a very busy recreational port with heavy ferry, cruise and fishing traffic. It is also a very popular area for scuba diving. The prevailing winds are northwesterly, and the outer harbour (Big Tub) is open to the northeast (with a long fetch), so docking in a brisk northeast wind is difficult due to heavy seas. The inner harbour (Little Tub) is well-protected. Offshore there are cross seas, due to wave/current interaction and channelling through the islands in the passage into Georgian Bay. There are extreme shoaling effects due to steep bottom slopes from very deep to shallow waters. As well, there is some reflection of waves due to the steep drop-off at the shoreline in some places. Confused seas are further built up by the refraction of waves off points and peninsula. There is often heavy fog with west winds in the spring and summer due to the extremely cold water.
2. **Entry to Georgian Bay:** Strong westerly winds funnel through the channels between Manitoulin and Tobermory, causing heavy seas (as high as 3-5 m). Current can be as strong as 3-4 kts (moving northeastward); and with strong winds or large barometric changes, Devil's Island channel can have particularly strong currents. Shoaling at the Great Barrier Shoals, east of the entrance to Georgian Bay, result in very turbulent seas, even with low wind speeds.

3. **Wiarton:** This recreational and fishing port is well-protected by a high coastline, except with northeast winds – but even then, the wave length is slightly dampened by islands at the mouth of the harbour. There are cliff effects along the eastern side of the Bruce Peninsula, and the resulting strong gusty winds can knock large sailing vessels down.
4. **Owen Sound:** This is a relatively busy recreational, commercial and fishing port. With southwesterly winds it may be gusty at the harbour mouth due to valley winds; and with east winds (which are rare) there may be significant wind set-up (more than ½ m) in the inner harbour, but the marina on the northwest is well-protected. Northeast winds increase through funnelling and cornering at Squaw Point and there are currents down the west side of the bay.
5. **Meaford** This fishing and recreational port has prevailing northwest winds. When the winds are northeast there may be heavy seas due to shoaling. The refraction of waves around the bend of the coastline increases wave heights. Currents run west to east at ½-1½ kts.
6. **Thornbury harbour:** This is a fairly busy recreational harbour which is exposed west-northwest through north to east-southeast. The high land (Blue Mountain) in this area causes gusty winds due to valley winds and cliff effects. Channelling of northwesterly winds causes convergence near shore and increased wind speeds. There are wind generated currents as strong as 1-1½ kts set to the east.
7. **Collingwood:** This is a recreational and fishing port. Shoaling at the Mary Ward Ledges (north and west of the harbour) results in heavy seas and difficult entry with the prevailing northwest winds. Convergence along the shoreline increases wind speeds, and there are currents of ½-1 kt flowing from west to east.
8. **Wasaga Beach:** At this small craft port, gradual shallowing of water begins about 8 km offshore and prevailing northwesterlies give a long fetch. As a result, there are long, rolling waves – excellent for windsurfing and small sailboats. There can be strong southwest winds due to funnelling and channelling due to the steep shores from Penetanguishene to Christian Island and east to the entrance to Midland Bay.

Silouetted sailboats at sundown.

9. **Midland:** There is heavy recreational and fishing traffic as well as commercial traffic at this busy well-protected harbour. High land, with many islands and inlets, causes a wide range of nearshore effects throughout this region. Northwesterlies funnel down the channel to the west, creating strong winds and heavy seas, but the harbour itself is not affected. In fall, northeasterlies can make waves reflect off shore, leading to higher waves. Cornering and refraction of waves around headlands create gusty winds and confused seas from Hope Island to Midland Bay Channel.

10. **Parry Sound:** This commercial and recreational harbour is protected from Georgian Bay effects, but out in the open, rough waters due to shoaling can take boaters by surprise.

11. **Parry Sound to Little Current** (inshore small craft route): It is possible to travel between Midland and Little Current sheltered from the open waves to Georgian Bay much of the time. However, in areas with steep islands and inlets there may be gusty winds and confused seas due to funnelling and wave/current interaction. The current is onshore in eastern Georgian Bay and winds south through west to northwest produce the heaviest seas. Seas build up due to shoaling about 2-8 km offshore. Some areas are exposed to heavy seas due to long fetch, notably from Little Current to Collins Inlet, from Pt. Gereaux to Bustard Island and from Byng Inlet to Hangdog Point. (This last area is particularly bad due to the added effect of extensive shoaling.)

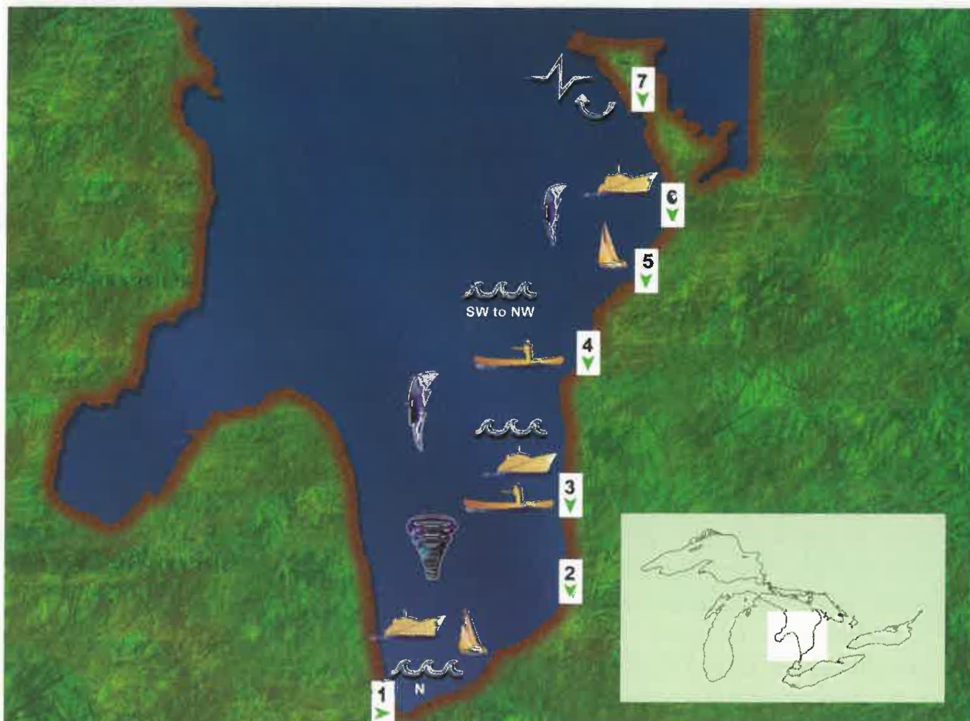
Conditions on Southern Lake Huron

(from Sarnia to the Bruce Peninsula)

General characteristics: The prevailing winds here are south to southwesterly. With winds from the southwest through northwest very heavy seas are generated along the entire eastern shore, which is exposed to the full fetch across the lake. Wind speeds average 15 kts in summer, but they have been reported as high as 50 kts in fall, with accompanying 5-6 m waves. The bottom slope near the 10 fathom line offshore causes steep and breaking waves.

With strong winds and sudden windshifts there is a significant set-up along this shore which can raise or lower water levels in harbours up to 1 m. Thunderstorms can produce the same effect over limited areas. There is sometimes little warning of thunderstorm activity on Lake Huron, so the wise boater will keep a sharp eye on the weather to avoid unpleasant surprises. Also watch out for waterspouts during cold air outbreaks, from August through October.

A 2-4 kt current, setting to the north, can be generated from Sarnia to Cape Hurd. This strong current can interact with waves from offshore and the confused seas at the steep bottom slope near the 10 fathom line, producing dangerous waves. Access to harbours is often difficult, with heavy and following seas.



1. **Sarnia:** This harbour has heavy commercial and recreational traffic, and offers very good (and popular) windsurfing conditions from Sarnia to Blue Cove. Channelling and convergence (along the west shore) create strong north to east winds, and the characteristic northerly winds cause high seas and produce a strong current moving south in the river. This south-moving current is accompanied by a reverse current along the Canadian shore, which boaters and windsurfers can use to advantage. The current under the Bluewater Bridge is typically 3-4 kts.
2. **Bayfield:** Entry to this harbour is difficult unless the wind is offshore (easterly). Onshore winds produce heavy breakers due to shoaling near the 10 fathom line. Water levels can rise ½ m (wind set-up) in the bay with northwesterly winds.
3. **Goderich:** There is mixed traffic – commercial, fishing and recreational – in this harbour. It is exposed from south to northwest, and southwesterlies make entry difficult for small craft. Short, steep waves create difficult boating conditions. There is a strong south to north current offshore.
4. **Kincardine:** This is a recreational and fishing port, protected from the northwest by a breakwater. However, with strong northwest winds there can still be some wind set-up. With westerlies, which are sometimes very strong, there can be heavy seas offshore. A strong, north setting 2-4 kt current has been reported offshore.
5. **Port Elgin:** This is a small port where windsurfing can be exciting. Prevailing northwesterlies combine with shoaling and refraction of waves to produce high waves, especially in the harbour. There is a strong south to north current offshore. Many thunderstorms coming across the lake come onshore here.
6. **Southampton:** There is mixed recreational, fishing and commercial traffic at this port, which is difficult to enter or leave with winds north-northwest through west to south. There is a strong northward current and there can be heavy seas offshore.

Children watching sunset on east shore of lake Huron.

7. **Stokes Bay (The Fishing Islands):** This is mainly a fishing area. The shoreline from Oliphant to Stokes Bay can be treacherous due to heavy confused seas and gusty winds – contributing factors are strong currents set to the north, a very long fetch, cornering and shoaling around islands, and channelling of northwest winds along the shoreline.

Conditions on the North Channel and Manitoulin

General characteristics: The orientation of the North Channel produces a prevailing westerly wind along its length. The winds are funnelled and increase in speed significantly in the Espanola area. East or west winds can produce large waves and wind set-up, as well as strong currents through straits and passages. Rapid pressure fluctuations during thunderstorms can also produce local jumps in water level. The east-west oriented channel extends 160 km, providing a long fetch, but the eastern end has about 50 km of islands that moderate the impact of this fetch. Be alert to local effects from high land and narrow passages.

Fog is less extensive over the North Channel than on northern Lake Huron in late spring and summer. However, showers and thunderstorms are more common here because they lose their punch over the cooler Lake Huron waters.

There are several well protected harbours and anchorages on the north shore of Manitoulin, including Little Current and Gore Bay.

1. **Great Duck Island and Burnt Island:** There is very little recreational or commercial traffic near this sheltered anchorage between Great Duck and Outer Duck Islands, and as

such it is quite peaceful. Anchorage at Burnt Island is generally well protected, but seas can be heavy with southwest winds.

2. **Western Straits:** Funnelling in Mississagi Strait, Detour Passage and False Detour Passage creates erratic doubling of wind speeds (due to high shorelines). There are strong currents in the straits.
3. **Meldrum Bay:** This harbour, with its stone dock, is well-protected, except from the north to northwest – with gales from the north to northwest there can be heavy seas. There is a strong current from west to east.
4. **Thessalon:** This recreational and fishing port is generally well-protected, but exposed to easterly winds. The steep islands and shoreline create a variety of nearshore wind effects, which cause confused choppy wave conditions when combined with shoaling.
5. **Little Current:** This is a busy area with a strong current, especially at the bridge. Without significant wind, the current is set to east at 0-2 kts; with strong westerlies it can reach 6-7 kts. With strong southeast winds a light current set to west may develop. There is channelling and funnelling down the North Channel and around islands. This combines with corner effects and shoaling around islands to produce choppy seas in the east end.
6. **South Baymouth:** This is a ferry port with some, but not too much, recreational and fishing traffic. Strong west through south winds cause heavy seas and currents which can be as fast as 4-5 kts at narrows. Wind set-up can raise water levels as much as 1½ m when there are southwest winds (long fetch).

Starboard of Ketch under a mackerel sky.

LAKE SUPERIOR

"Whitefish Bay is notorious for its rough waters. ... [A] very high percentage of the ships that have ever sunk in Lake Superior have gone down in Whitefish Bay. It's here that the Edmund Fitzgerald was lost in a terrible storm in November 1975."

– Mary Jo Cullen, in QAYAQ, Winter 1997.

"To me the Great Lakes will always mean Lake Superior ... There is something singularly impressive in the mere silence and vastness of our great northern solitudes."

– Alice Wellington Rollins.

Freighter in steam fog.

Introduction

Lake Superior is enormous. It holds 12,100 km^3 of water, reaches a maximum depth of 405 m, and covers an area of 82,100 km^2. It could hold all the other Great Lakes, with three extra Lake Eries. It is also by far the deepest and coldest of the lakes. The air temperature over it averages less than 15ºC in summer, whereas on Lake Erie the average summer air temperature exceeds 20ºC. Because it is so large and cold, it, more than any other lake, creates its own weather regime.

Meteorologically, Superior can be divided into two distinct areas. On western Lake Superior, from south of Isle Royale to Duluth, the prevailing winds are from the northeast or southwest (due to channelling), while on central and eastern Lake Superior, from Thunder Bay to Whitefish Bay, prevailing winds are from the northwest. However, since most of the Canadian waters of Lake Superior are in the central and eastern portion, we have treated the lake as one area in the section that follows.

Fog is a major problem on the lake, particularly in spring and summer. This is because water temperatures usually do not rise much above 10-14ºC. Superior's average water temperature in May-June is 10-12º lower than the lower lakes. Even in August it only reaches 14ºC, whereas the southwestern basin of Lake Erie exceeds 24ºC. As a result of these cold water temperatures, from April through July, any weather regimes with dew point temperatures above the water temperature produce extensive fog, as the relatively warm, moist spring air condenses above the cool Superior waters. June is the worst month for these fog banks, which are almost a permanent feature over the whole lake including nearshore areas from

Sault Ste. Marie to Thunder Bay. In July, fog frequency drops dramatically along the east and west shores due to a significant warming of lake surface temperatures.

In fall and winter, winds over the lake are often 10-15 kts stronger than over land. This is because the lake has reached its maximum temperature by early fall, at which time cold air is being driven down from the north. This arctic air produces instability over the warmer water, which in turn results in very strong, cold gusty winds being drawn down to the lake surface. Strong Wind Warnings are issued from May to November when winds are 20 kts or more. Wind speeds in summer only get that strong 10% of the time, whereas in fall and winter they reach that threshold 40% of the time.

Wind set-up and seiches are generally of little significance on Lake Superior – 40 kt winds will only raise water levels by 15 cm in most cases. However, the narrowing and sloping of some bays at the east end of the lake (near Sault Ste. Marie, for example) can amplify the set-up effect, and maximum increases in water level approaching 1 m have been reported.

In the summer, waves average less than 2 m in height, but they can get as high as 6 m occasionally. In winter, waves are higher, averaging 2-3 m and, in extreme cases, reaching 10 m. It is important to keep in mind that seas may be higher or choppy and confused in locations where nearshore effects, currents or thunderstorms interact with overall wave patterns.

The Canadian shores of Lake Superior loom steeply out of its waters, setting the stage for vicious winds off the high land and a great many nearshore wind effects. However, since much of the shoreline is sparsely populated, there is little documentation available on local experiences. The combination of coastal convergence, cornering, funnelling and channelling all contribute to diverse local effects, but only some of these are specifically identified in the description of local conditions which follows. If you are boating in an area which is poorly documented, combine the knowledge you have of local topography and waters with your understanding (from this guide) of when you might expect to encounter the various nearshore effects. Please let us know about significant local conditions we may have missed. (See contact information on page 151).

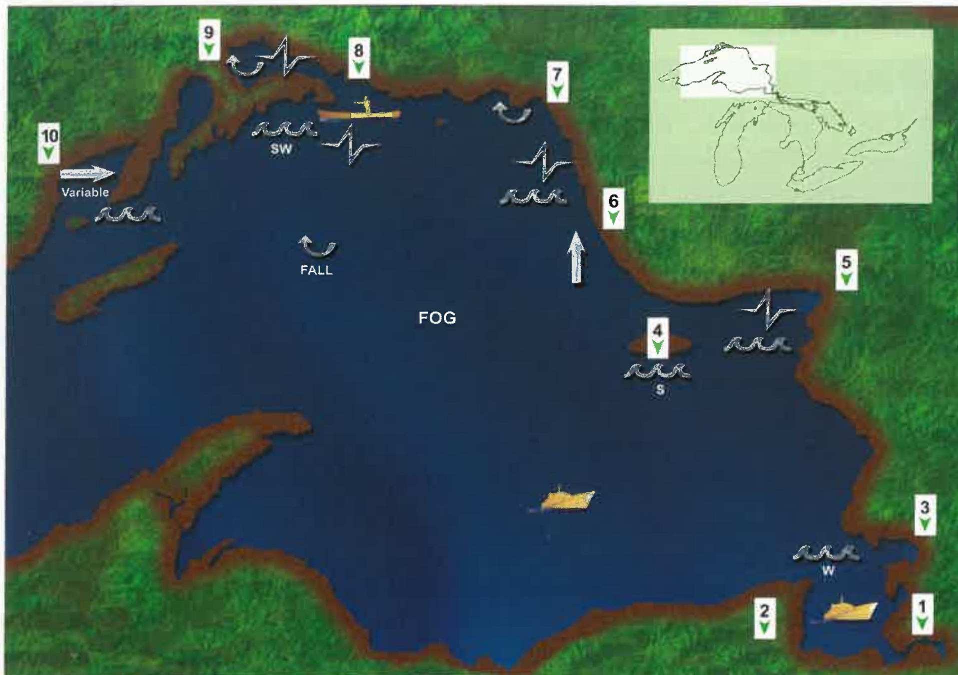
Thunderstorms on Lake Superior are usually associated with cold fronts, but they lose some of their strength as they move from the warmer to the cooler waters of the lake. Squall lines, which typically move from west to east across the lake, are usually much weaker by the time they reach the eastern shore.

There is very little precipitation on Lake Superior during the summer – it rains only 5% of the time. In the winter, however, there is precipitation about one third of the time, often combined with freezing spray.

A very real danger is presented to vessels that ply Superior late in the season, when they always hug the north shore for safety. Early in the century, shipping was heavy on Lake Superior, and it was during this era that many of Superior's worst tragedies occurred. In November and December freezing spray can cause severe icing, and November is also the month that has seen some of the worst tragedies on both Lake Superior and Lake Huron. Ships such as the Edmund Fitzgerald (lost more recently in 1975) have disappeared with all hands in Superior's occasionally ferocious November storms. But over all, Lake Superior is fairly predictable – although sometimes predictably treacherous!

Conditions on Lake Superior

1. **Sault Ste. Marie and the St. Mary's River:** This area is relatively sheltered from weather on Whitefish Bay. River traffic is heavy, but carefully regulated. With strong northwest winds there may be up to 1 m set-up (rise in water level) northwest of the locks.
2. **Whitefish Bay**: This bay is relatively sheltered, with heavy commercial traffic. It is common anchorage for waiting out Superior storms. When there are strong westerly winds there may be heavy seas.
3. **Batchawana Bay:** With strong southerlies, anchorage behind the government docks may be uncomfortable. Harmony Bay or Havilland Bay provide protected shelter. Watch for heavy and/or confused seas at the west end with strong onshore winds (from south through west), due to shoaling and nearshore wind effects. The steep deepening of the lake bottom between Cape Gargantua and Whitefish Bay causes choppy seas due to shoaling when winds are westerly.
4. **Quebec Harbour (Michipicoten Island):** One of the best sheltered offshore anchorages on Superior, for vessels up to 100 m in length. With strong northwest winds there is a strong easterly current in the harbour entrance. The reflection of waves with strong south winds can create heavy seas.
5. **Michipicoten Harbour and Michipicoten River:** With west or southwest winds Michipicoten Harbour can be a "mean place" for large vessels. Winds from the south through west channel to become southwest and true southwesterlies are amplified by 25-40% due to funnelling. A strong current at the Michipicoten River entrance creates bad cross seas (wave/current interaction) and choppy seas off Lighthouse Point.
6. **Otter Head:** The very steep shoreline from Otter Head to Marathon causes convergence with southerly winds, and cliff effects with northeast or southwest winds. The reflection of waves creates confused seas with strong southwest winds. With strong northeast winds, drops in water level due to seiche are reported to be sufficient to let small craft touch bottom occasionally.
7. **Marathon:** This horseshoe-shaped harbour is surrounded by high land and provides excellent protected shelter. However, the high walls also trap pollution, making it unpleasant. There are often valley winds, resulting in gusty, shifting winds outside the harbour when general lake winds are southerly.
8. **Rossport and Battle Island:** This is a sheltered harbour for small craft. Between Wilson Island and Salter Island and off Moffat Strait there are cross seas. Westerlies can cause high seas south of the islands because there is a long fetch; the glass in the 14 m high lighthouse lantern at Battle Island has been broken by waves. Valley winds and cliff effects are likely between Schreiber and Terrace Bay.
9. **Nipigon Bay:** This is a shallow, relatively landlocked bay, with five entry passages, all with steep, high walls, and several steep, small islands within it. It is a likely location for funnelling, shoaling and wave/current interactions. There are strong currents, often in opposition to the wind, and the west end of the bay is very gusty with high seas



(2 m) when there are south or southwest winds (funnelling). East or west winds can cause steep, choppy seas, due to the combination of shallow waters, steep islands and currents.

10. **Thunder Bay:** With southwest or northeast winds, there are frequently steep and chaotic seas between Cape Thunder and Pie Island, due to funnelling/channelling of winds just outside the harbour. Along this stretch of Superior, the predominant northeasterlies/southwesterlies outside of bays produce strong wind changes at bay mouths. The interaction of these channelled winds outside the bay with onshore breezes (lake breeze) makes winds variable and difficult to forecast in the bay. Avoid trying to go between Pie Island and the Mainland, because it is dangerous with almost any wind direction. Westerly winds over the high ski slopes produce a cliff effect, with a calm area near Pie Island, and then a sudden increase in wind speed further out. Southerly winds can also be bad, and the fetch in the bay is long enough to produce 2-3 m waves. There is a swift current (1-1½ kts) down channels into the bay, and east to east-northeast winds make the breakwater difficult to manoeuvre.

"Those who have never seen Superior get an inadequate even inaccurate idea by hearing it spoken of as a lake … Superior is a sea. It breeds storms and rain and fogs … It is cold, wild, masterful and dreaded."

– Reverend George Grant, 1872, quoted in *Kanawa*, Winter, 1995

SMALLER LAKES

Sailboarders.

Introduction

Boating in Ontario is by no means confined to the Great Lakes. There are many medium and small lakes with extensive recreational activity and some commercial ventures such as fishing and cruising. Medium sized lakes, such as those discussed separately in this section (Simcoe, Nipissing, Nipigon and Lake of the Woods) are big enough to have their own recreational boating forecasts. Boaters on smaller lakes and rivers with no recreational boating forecast can listen to the public forecast and apply the general principles discussed in this guide.

Wind and weather conditions on inland lakes reflect the competing influences of land and water. On the small lakes, boaters are never more than a few kilometres from shore, so they feel the effects of land winds. Also, smaller, shallow lakes heat up much more quickly than the Great Lakes do, reducing the land/lake temperature contrast. Therefore, winds on small lakes tend to be gustier in spring and summer than on the Great Lakes. The lake breeze effect is also less significant on smaller lakes such as the Muskokas and Kawarthas than it is on the larger lakes.

Thunderstorms tend to be more frequent on the small lakes than they are on the Great Lakes because smaller lakes do not have large enough expanses of cold water to dampen the strength of thunderstorms moving off the land. These storms may also take boaters by surprise in areas where high land and forest block the view of incoming storms.

However, for the most part, wind and weather effects are governed by the same forces as they are on the Great Lakes, but operate on a smaller scale. For instance, wave heights are generally less than 1 m because the fetch and lake depth on a smaller lake doesn't allow waves to build to extreme heights. However, these shorter waves may still be steep and choppy, especially on medium sized shallow lakes like St. Clair and in areas with heavy small craft activity.

Boating traffic on smaller lakes is predominantly recreational. It can be very heavy in cottage areas, and the wide variety of recreational activities supported by some of these lakes demands close attention to safe boating practices.

On rivers and canal systems the same conditions apply, but boaters should be alert to the interaction of river currents with wave conditions and the possibility of funnelling and valley effects. It should also be noted that lightning creates special problems in the locks of canal systems, in that they are lined with highly conductive materials and the power supply to the locks can be disrupted by lightning strikes. If you are expecting to enter the locks listen for weather watches/warnings so that you do not find yourself stranded there during an active lightning storm.

Lake Simcoe

> *"We spent a few years on Simcoe. The seas would become quite steep in a short period of time. They'd also correct quickly. The one thing I found with Simcoe – there's a lot of wake-induced waves there."*
>
> – Peter Stott.

General characteristics: Lake Simcoe, like the Muskokas and other smaller lakes in "cottage country", is very busy with recreational boating of all types. Its proximity to Toronto makes it particularly popular, and it is also an important link in the Trent and Severn Waterways. The main body of the lake is about 30 km long and 24 km wide, with more than 230 km of shoreline. Because it is too busy, seas can be choppy, with many wake-induced waves. Thunderstorms occur relatively frequently and are sometimes severe. They can change conditions very quickly on the lake, producing dangerous wind, waves and weather with little warning, so boaters are well-advised to stay alert to changing weather conditions. With the prevailing west-northwest wind, the east side of the lake is exposed to heavy seas.

1. **Barrie/Kempenfelt Bay:** Kempenfelt Bay is 14 km long, with a maximum depth of 42 m and no shoals, so it provides a calm, safe harbour at Barrie, at the west end of the bay, when the prevailing westerlies are blowing. Barrie is a busy recreational harbour, with sufficient water depth (1-4 m) at the Bayfield Wharf even for larger vessels. In high winds, there are rough seas just east of the mouth of Kempenfelt Bay, and with northwest winds, cross currents and erratic wave patterns are prevalent. The west shoreline of the lake is generally protected from the prevailing winds, but not far offshore, strong winds can stir up 1 m waves. Further offshore, Long Shoal, which is well marked, produces shoaling effects.
2. **Atherly/Lake Couchiching:** The narrows into Atherly are well-protected by a number of islands, and there is heavy recreational boating traffic at this entry to the Severn Waterway.
3. **Lagoon City:** Popular for recreational boating, with a well-protected breakwater. Shoaling in shallow waters north of the harbour.
4. **Beaverton:** Heavy recreational boating and plentiful marina facilities. Safe haven from rough waters which occur with prevailing winds on the east shore of the lake.
5. **Georgina Island:** Marine facilities available at Jackson's Point and along the Pefferlaw River.

October sunset.

Smaller Lakes

Georgina is the largest island on Lake Simcoe. The water is shallow south of the island, so make sure you know these waters well enough to avoid hitting bottom.

6. **Cook Bay:** There are several marinas and heavy recreational boating in this shallow bay, which is generally calm, except with winds from the north-northwest. With north-northeast winds, high waves pile up in the shallows. Small boats can enter the Holland River through this bay, but only those that can negotiate under low bridges.

Lake Nipissing

General characteristics: With a surface area of 831 km^2, Lake Nipissing is much smaller than any of the Great Lakes. The Ojibway name for it means 'little water'; a reference to its size in comparison to Georgian Bay. It is also much shallower than Georgian Bay, averaging 4.5 m in depth and reaching its greatest depth (52.5 m) near the mouth of the French River. Because it is so shallow, effects from high winds can cause strong wave action. The lake's east-west orientation gives it a fetch of 80 km, long enough to produce wind set-up with westerly winds.There is moderate recreational boating on the lake, much of it from fishing. In the summer, the prevailing winds are southwesterly (Southwest through West-southwest). The next most common wind direction is north. Southwest winds are common following the passage of warm front, and can be strong (greater than 15 kts) and sustained (lasting more than 12 hours). As a result, waves can reach 2 m on the east half of the lake due to the long fetch. Prolonged westerly winds also cause significant wind set-up along the inhabited east shores, with seiche of up to ½ m over 24 hours.

There are often squalls and gusty winds out ahead of cold fronts, and thunderstorms with frequent lightning on cold fronts, which approach quickly, giving little warning.

Northerly winds are common after a cold front moves through, and rapid and substantial changes in wind speed and direction stir up confused seas in the front's wake. These strong winds and heavy seas are the most common navigational hazard due to weather effects, followed by thunderstorms and heavy precipitation (causing poor visibility).

Nearshore wind effects are less significant on Lake Nipissing than on Georgian Bay because the shoreline topography is generally lower and less convoluted.

There is little hazard from currents or fog. The lake is too shallow to experience significant advection fog, radiation fog on calm summer mornings generally burns off by midmorning, and warm frontal fog occurs only occasionally.

1. **North Bay:** This is a busy recreational port for cruising, sailing and fishing. There is sand shoaling about 500 m offshore from North Bay to the Lavase River. Prolonged Southwest winds can create waves 1-2 m, and if strong westerlies persist longer than 12 hour waves may be greater than 2 m. Moderate to strong westerly winds combine with shoaling to create heavy seas along the entire eastern shoreline. On summer afternoons the lake breeze effect can build onshore winds from calm to 10-15 kts within 10 minutes, and these winds persist in to the late evening, stirring up more than ½ m waves within fifteen minutes of their onset.
2. **Callander Bay:** This is a sheltered harbour with considerable recreational and fishing activity. Boaters can be taken by surprise by approaching thunderstorms and gusty winds. Funnelling of east or west winds through the harbour entrance can increase wave heights, and strong northeast or northeast winds combine with the shoreline topography to stir up choppy and confused seas.
3. **The south shore and South Bay:** There is some recreational and boating traffic here, but northerly winds frequently create high seas. Crossing the lake from Deepwater Point to Cross Point can be treacherous, with full exposure to wind and wave action from all

directions. Parts of South Bay provide protection, but the many islands combine with winds to produce gusty winds and confused seas.

4. **The French River entrance:** Busy recreational boating, including canoe and kayak traffic. The river mouth is protected, except from southwest or northeast winds, which can create high seas. Cold frontal thunderstorms approaching from the west or northwest may surprise boaters because of the shoreline topography. There is shoaling near the entrance as the river bottom rises from more than 50 m to meet the much shallower lake bottom.
5. **West Bay:** This area has less boating traffic and is somewhat protected from prevailing winds by its topography. Islands and shoals can create confused seas, and with easterly winds the long fetch builds waves to 2 m, with ½ m rises in water level due to set-up in some of the bays and channels.
6. **The west arm:** This area has heavy recreational and fishing traffic, and offers many protected bays and channels. There is little wave action, except in a few channels where funnelling with north or south winds produces locally confused seas.
7. **Cache Bay and the north shore:** The north shore has considerable recreational and fishing traffic, and some commercial. Cache Bay is a protected harbour but with winds from the south, the north shore is generally exposed. Southerly winds funnel on the Sturgeon River and its entrance is subject to strong wave action with winds from east to west through south. The river current is less than 2 kts and poses little hazard. West of the Sturgeon River shoreline topography, shoaling and islands produce choppy seas but some shelter. East of the river there is little protection.
8. **The Manitou Islands:** This recreational and fishing area is exposed to the prevailing winds, but the islands provide some protection from wind-driven wave action. Winds can become strong with little warning, so boaters are wise to head toward shore at the first indication of increasing winds. Steady winds produce long rolling waves all around the islands (due to the fetch), and with the onset of winds greater than 15 kts (from any direction) 1-2 m waves can develop within an hour.

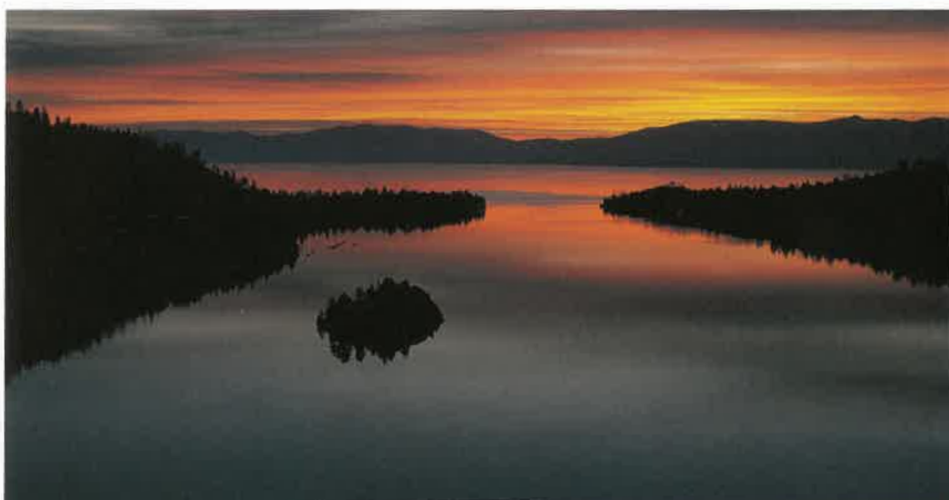
Lake Nipigon

General characteristics: Lake Nipigon is larger than Lake Nipissing, at 88 km wide and 128 km long (north/south), but it is more remote and less busy. There is some commercial and recreational fishing traffic, as well as recreational boating. The paucity of marine traffic becomes a hazard in itself for boaters who need help unless they are able to establish radio communications with the commercial fishing operations.

Nipigon is, for the most part, deep, reaching an estimated 100-180 m depth at the centre. It has never been formally charted. Its shores (and the shoes of islands within it) are mainly steep and rocky, and they offer very few bays and protective harbours. The strongest winds and highest waves are most likely to occur with the passage of cold fronts over the lake, the most vigorous of which occur early and late in the boating season. Strong northerly winds whip waves up to 3 m high very quickly, and northeasterly winds are strengthened by convergence due to channelling along the west shore. Thunderstorms are not as frequent to Lake Nipigon as on more southern lakes, but when they occur they can produce dangerous squalls and high waves in short order.

The lake's rugged islands produce a full range of nearshore wind effects, including cornering and cliff/lee effects, but they also serve to break up the long fetch, which would otherwise run 128 km with north/south winds.

1. **Ombabika Bay:** This bay on the northeast end of the lake provides some shelter, except from strong northeast/southeast winds, which can create high seas. There may be funnelling of winds through the entrance to the bay with north or south winds.
2. **Humboldt Bay:** There is little protection from westerly winds here, except behind the islands within the bay. The bay does provide shelter from other wind directions.



Sunset over lake.

3. **Orient Bay:** This is a commercial fishing and recreational harbour, with a provincial park at the mouth of the bay. This narrow bay provides safe shelter from all but northwest/southeast winds and associated waves.
4. **South Bay to McIntyre Bay:** There is some commercial fishing on South Bay. McIntyre Bay is well-sheltered. It's only access is opposite Shakespeare Island, which may produce some corner and lee effects.
5. **Grand Bay to Gull Bay:** These bays are small, but Gull Bay provides some shelter from winds and waves in the centre of the lake.

Lake of the Woods

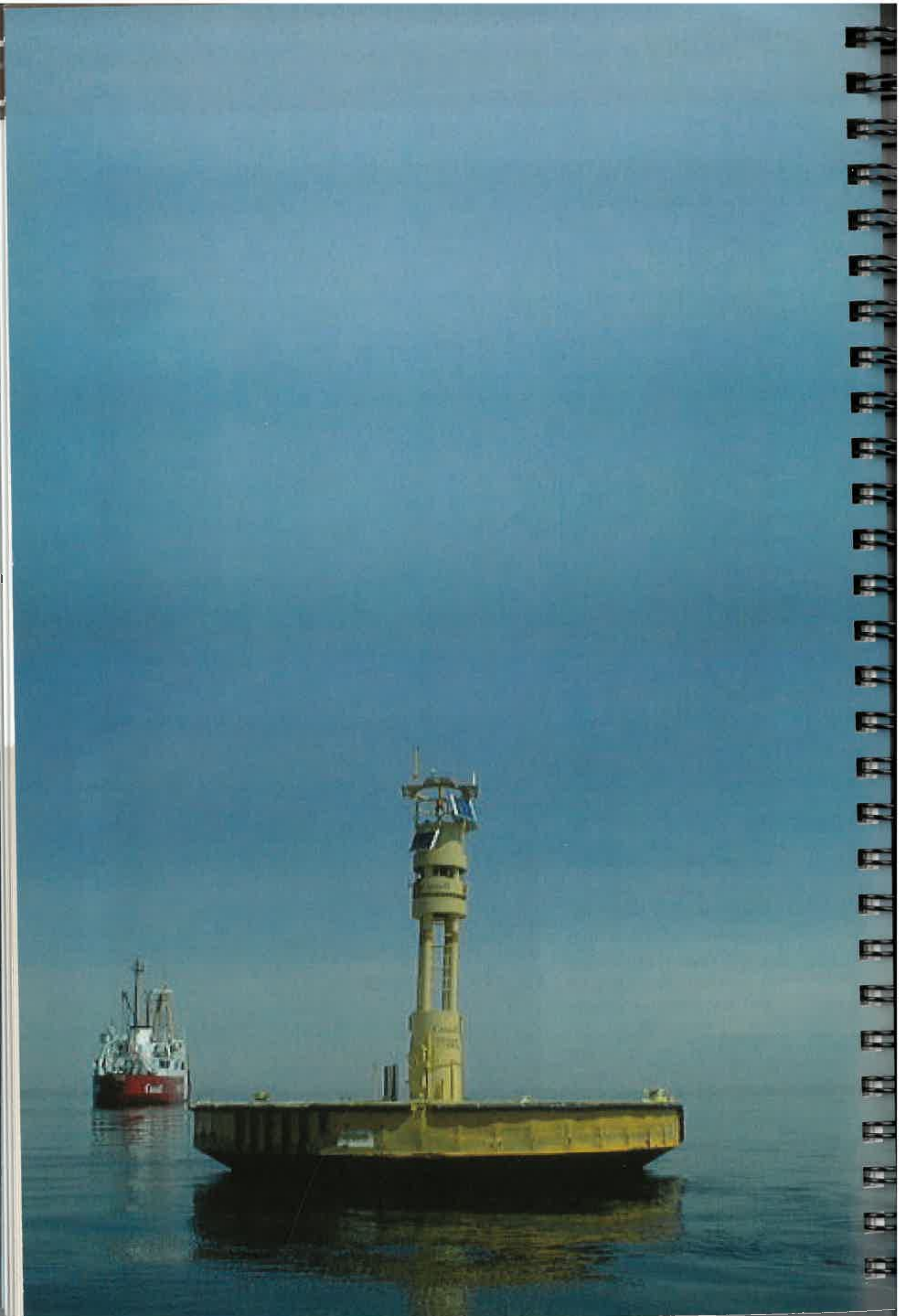
General characteristics: There is busy recreational boating of all types on this lake, which includes both U.S. and Canadian waters and is lined with many tourist facilities and marinas. This 4,350 km^2 lake (3,149 km^2 of which is in Canada) is the remnant of glacial Lake Agassiz, and has many inlets and islands. It is 112 by 102 km, but boasts more than 6,500 km of shoreline on the mainland, and 4,000 km shoreline on its 14,632 islands. The inlets and islands, many of which are steep and rocky, make Lake of the Woods an ideal demonstration ground for the nearshore wind and wave effects discussed earlier in this guide.

The mean water depth in Canadian waters is 7.9 m, with a maximum depth of 68.8 m in Whitefish Bay, east of Sioux Narrows. The U.S. portion of the lake is shallower and sandier, particularly at Big Traverse Bay. The water level is controlled and is allowed to fluctuate by 0.5 to 1.2 m.

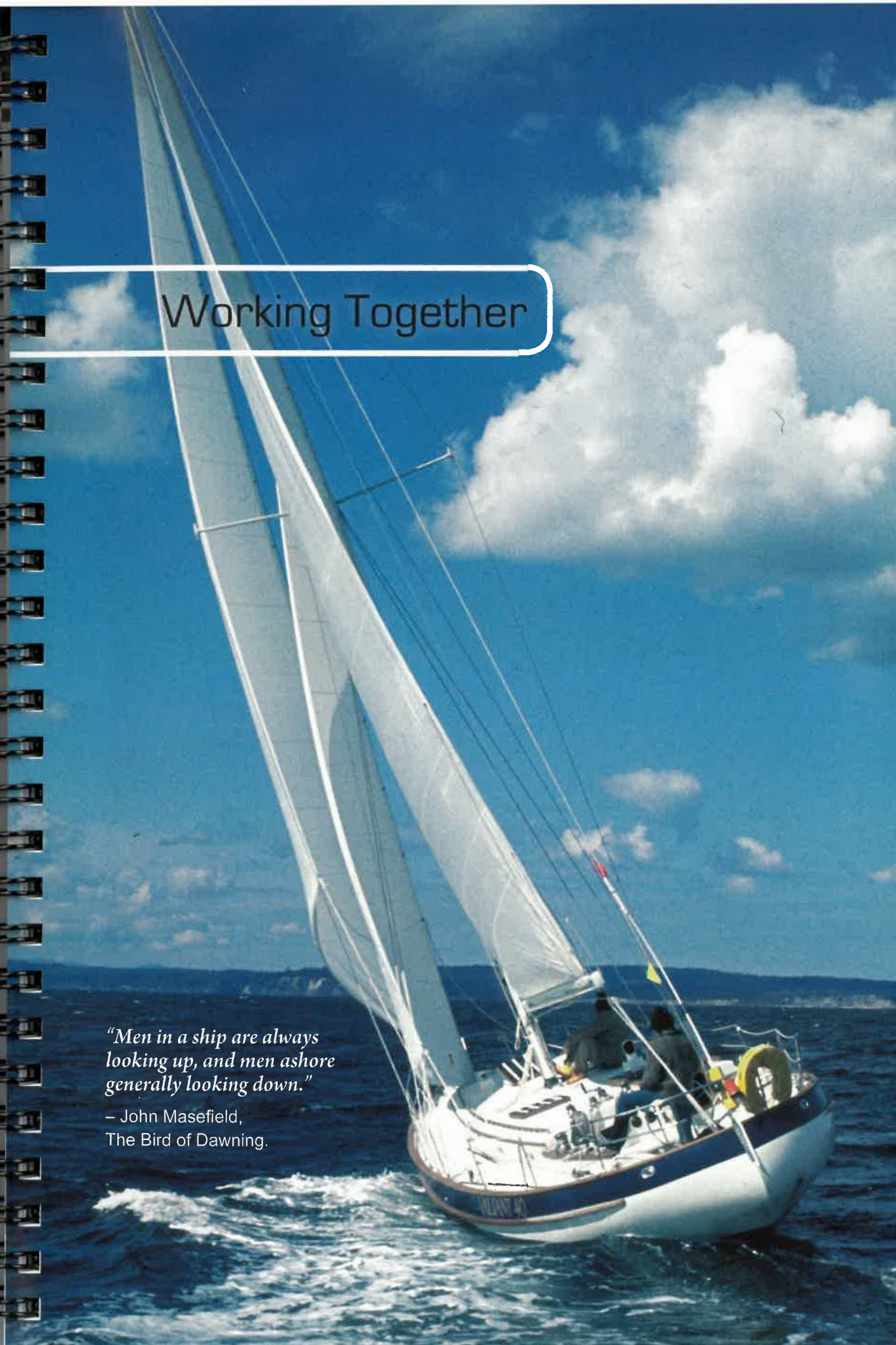
There are frequent thunderstorms on the lake, including both frontal and isolated airmass storms. Cold fronts which cross the area with prolonged, brisk NW winds produce high seas and strong gusty winds; and intense lows which pass south of the lake in spring and fall can produce sustained east winds, which can also build large waves.

Lake of the Woods was part of the fur trade and voyageur route in early Canada and it also holds much interest for Native American history, including rock paintings at several sites.

1. **North of the Aulneau Peninsula:** This is a busy recreational boating area, particularly near Kenora. Its many islands provide protection from wind and waves, but also produce many nearshore wind effects. Winds from the northwest and east can produce 1-2 m seas. Watch particularly for funnelling in channels and corner and cliff/lee effects around islands.
2. **Big Traverse Bay:** This sandier, much shallower area has busy recreational traffic, and its waters get stirred up into high seas more easily than the deeper part of the lake. It is also more open (the bay is approximately 50 by 64 km) and provides a fairly long fetch for winds from the North to Northwest and from the East. Winds along this fetch can build waves up to 3 m high. High seas create an increased risk of bottoming out in the shallow waters of the bay.



Working Together



"Men in a ship are always looking up, and men ashore generally looking down."

– John Masefield,
The Bird of Dawning.

MARINE WEATHER SERVICES .... What we have to offer you

Weather Buoy on Lake Ontario.

Weather is always changing, and local factors (topography, coastline, currents, water depth and temperature, fetch) cause local variations to general effects. To keep on top of changes in the weather, boaters and the Weather Service must work together. Environment Canada operates Canada's Weather Service which offers a broad range of products and services that are designed to help boaters make informed decisions on how weather will affect them. The Canadian Coast Guard (CCG) also plays an important role in disseminating forecasts and warnings and in collecting and relaying weather observations from volunteer observers and ships.

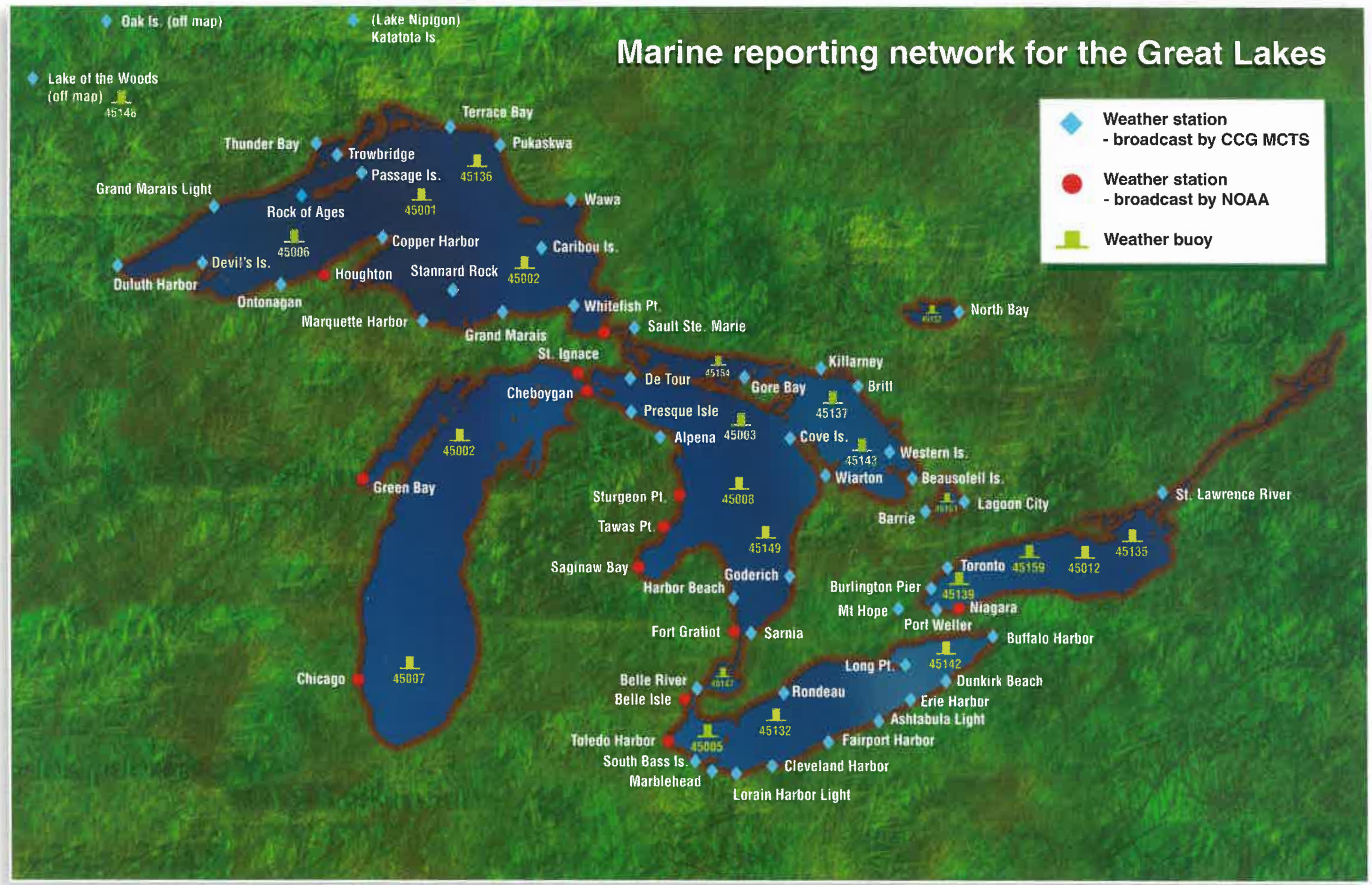
These resources, combined with your boating skills and awareness of local hazards, will help you develop an alert weather sense. With an understanding of current weather and forecast conditions and a keen eye to local changes and peculiarities, you can increase your enjoyment and safety.

Gathering the information you need

So, you're planning an excursion on your boat and you want to know what to expect from the wind and the weather? People at Environment Canada are busy 24 hours a day, year-round collecting and analyzing data and producing forecasts to give you the weather information you need.

Much of this information comes from volunteer observing ships, weather buoys, automated stations, and Environment Canada Storm prediction centres; all of which supply a constant stream of data (see map, opposite page). And this is supplemented by satellite imagery, weather

Marine reporting network for the Great Lakes



radar, lightning detection data and information collected through the MAREP program. (This program, formerly called SCREP – Small Craft Reporting Program – is discussed on page 138).

What kind of information can you get?

At the Ontario Storm Prediction Centre in Toronto, this information is amassed, analyzed and translated into forecasts and charts to suit varied locations and needs. Those of special interest to you as a boater are marine and weather warnings, marine forecasts (offshore), recreational marine forecasts, and the marine observations summary; all of which are broadcast in regular cycles on Weatheradio.

For your general interest, you can get public forecasts, the long range outlook and current weather observations by listening to Weatheradio or calling the recorded message at your regional weather centre.

Marine warnings, watches and advisories

Special bulletins, which are broadcast immediately on marine radio by the Canadian Coast Guard, are issued when weather, wind or water conditions may pose a threat during the 48 hours forecast period.

On Environment Canada's Weatheradio, warnings are issued as part of the regular marine and recreational marine forecasts. Of special note to boaters are:

During the recreational boating season:
Strong wind warning – Sustained winds of 20-33 kts are expected.

Throughout the year:
Gale warning – Mean wind speed is expected to be 34 to 47 kts.

Storm wind warning – Mean wind speed is expected to be 48 to 63 kts.

Hurricane force wind warning – Mean wind is expected to be 64 kts or more.

Watches and warnings are also produced for the following conditions as necessary:
Squall watch/warning – Wind gusts of 34 kts or more usually associated with convective clouds.

Waterspout watch – When conditions are such that waterspouts or cold air funnels and likely. Waterspout watches may be issued for any of the Great Lakes and for the smaller lakes covered by Recreational Marine Forecasts.

High water level warning – When surge or wind/wave conditions which may cause damage to property or endanger lives exist.

Freezing spray warning – When the ice accretion rate is expected to be 0.7 cm/hr or more.

Boaters should also be alert to watches and warnings related to severe weather, which are discussed on page 65 in *When the Elements Rage*.

Marine forecasts (Great Lakes and St. Lawrence River) (offshore)

The marine forecast is available year-round (three times a day in the recreational boating season, and twice a day in the winter) and consists of the average wind and weather conditions over the open water of the lakes, away from the modifying effects of the shore. It consists of a textual forecast for the lakes as follows:

Forecasts for: Lake Superior, Whitefish Bay, Lake Huron, Georgian Bay, Lake St. Clair, Lake Erie, Lake Ontario and the St. Lawrence River from Kingston to Cornwall.

Each containing:
Watches and warnings, Marine Weather Statements (if any),
wind speed – Significant changes in speed and direction, average speed for 10m level,
wind direction – winds generally from this direction – the suffix "erly" means variable,
Visibility-Visibility less than or equal to 1 nautical mile,
weather – the main weather effects on the lakes,
Freezing Spray- for the winter season,
waves, amplitudes are measured from trough to crest, for offshore area.

A Technical Marine Synopsis is also issued 3 times daily that provides users with information on the location of the centres of high and low pressure systems over the 48 hours of the forecast period.

These pieces of information can help you understand the general weather situation and adjust the forecast to your actual position. With the barometric pressure (available at any time by listening to Weatheradio), you can mark your barometer and check later to estimate when a front or trough is close to you.

Marine weather statements (MWS) are non-scheduled, event-driven products when marine weather conditions consistent with the issuance criteria are present or forecast.

The MWS is a free form text that provides the public with detailed marine weather information describing non-severe, but potentially hazardous conditions; and other information about a variety of conditions not covered by warnings or routine forecasts.

A coded message, called the MAFOR, is included with the synopsis. Its greatest usefulness is for international vessels, because the numerical code makes it independent of language. It is a short form translation of the offshore forecast. Although the same information is available to nearshore boaters in plain language through the marine forecast and synopsis, many recreational boaters still enjoy knowing and applying their knowledge of the MAFOR code as a "hats off" to marine tradition.

Whether you look to the plain language marine forecast or the MAFOR, it is important to take into account the fact that they are based on information gathered at the middle of the lakes, and you will likely be boating nearshore, where local effects and conditions vary. The knowledge you have gained of nearshore effects from earlier in this guide, will help you read the forecasts in the light of local conditions.

Marine forecasts are issued three times a day at 3:00 am, 10:30 am, and 6:30 pm Eastern time. Forecasts are valid until midnight of day 2, with an extended forecast period covering day 3, 4 and 5. However, for the St. Lawrence River, forecasts are normally not issued from December 31 to March 15 due to freeze-up of the St. Lawrence Seaway.

Weather observations are taken throughout the Great Lakes Region.

MAFOR TABLE

MAFOR YYG1G1 (NAME OF LAKE) 1GDFmW1

Keyword (Indicating Marine Forecast)	DAY OF MONTH (GMT)	TIME (GMT) FORECAST PERIOD BEGINS	SOLIDUS	NAME OF LAKE OR SEAWAY	GROUP INDICATOR	FORECAST PERIOD	WIND DIRECTION	WIND SPEED	FORECAST WEATHER
	yy	G1G1				G	D	Fm	W1
MAFOR	06	12	(/)	SUPERIOR	1	6	8	3	0

G – FORECAST PERIOD

0 – Conditions of beginning of forecast period
1 – Valid for 3 hours
2 – Valid for 6 hours
3 – Valid for 9 hours
4 – Valid for 12 hours
5 – Valid for 18 hours
6 – Valid for 24 hours
7 – Valid for 48 hours
8 – Valid for 72 hours
9 - Occasionally

D – WIND DIRECTION

0 – Calm
1 – Northwest
2 – East
3 – Southeast
4 – South
5 – Southwest
6 – West
7 – Northwest
8 – North
9 - Variable

Fm – WIND SPEED

0 – 0 to 10 knots
1 – 11 to 16 knots
2 – 17 to 21 knots
3 – 22 to 27 knots
4 – 28 to 33 knots
5 – 34 to 40 knots
6 – 41 to 47 knots
7 – 48 to 55 knots
8 – 56 to 63 knots
9 – 64 knots and above

W1 – FORECAST WEATHER

0 – Moderate or good visibility, more than 3 nautical miles
1 – Risk of accumulation of ice on super structures (Temp. 23° to 32° F.)
2 – Strong risk, accumulation of ice on superstructures (Temp. below 23°F.)
3 – Mist (visibility 5/8 to 3 nautical miles)
4 – Fog (visibility less than 5/8 nautical miles)
5 – Drizzle
6 – Rain
7 – Snow, or rain and snow
8 – Squally weather with or without showers
9 - Thunderstorms

For U.S. information

For information concerning the U.S. National Weather Service contact the Port Meteorological Office, Cleveland, Ohio, telephone (216) 265-2370 or Chicago, Illinois, telephone **(815) 834-0600 ex 269.**

Recreational marine forecast

During the recreational boating season, (May 1st to November 30th), recreational marine forecasts are also available for some of Ontario's smaller lakes and boating areas (except when the lakes are still ice-covered). These forecasts include a detailed marine forecast valid until midnight of day 2 and are issued at 5:00 am, 11:30 am, and 5:00 pm Eastern time. They also include Strong Wind warnings for winds more than or equal to 20 kts.

The boating areas for which recreational marine forecasts are currently available:

Lake Simcoe (May 1 to November 30)
Lake Nipissing (May 1 to November 30)
The North Channel (May 1 to November 30)
Lake Nipigon (May 1 to November 30)
Lake of the Woods (May 1 to November 30)

Where can you get forecast information?

Environment Canada offers direct contact with a forecaster by using the user-pay **1-900-565-6565** (marine weather line).

Weather information is available, not only from the Ontario Storm Prediction Centre, but also through Weatheradio, Canadian Coast Guard (CCG) Communication and Traffic Services (MCTS) Centres, the public media (via the Canadian Press Wire Service). There are also various websites that can provide weather information (see Getting on-line, below).

Western Island

Weatheradio

Weatheradio Canada is operated by Environment Canada and provides the most up-to-date warning and forecast information available. This weather information is transmitted over seven dedicated VHF bands: 162.400, 162.425, 162.450, 162.475, 162.550, 162.525 and 162.550. Details on marine and other weather is presented in continually repeated program cycles which average 5-7 minutes, but may vary slightly from one area to another. This information is updated as new reports and weather bulletins become available.

Program cycle contents are adapted to seasonal needs and programming may be interrupted at any time to broadcast weather warnings. Many Weatheradio receivers are equipped with a "tone alert" which automatically emits a loud, continuous tone when a weather warning is issued. Weather warnings are broadcast for significant weather events, including severe thunderstorms and heavy rain. (See page 68 for more details on weather warnings.) However, marine wind warnings are not broadcast separately and the tone alert does not sound for them. If a marine wind warning is in effect it will be mentioned in the appropriate marine and/or nearshore forecast.

Weatheradios are very useful for anyone whose activities are influenced by changes in the weather, and it is wise to have one with a "tone alert". They are available from popular radio retail stores.

Marine Radio (CCG)

The Canadian Coast Guard Marine Communication and Traffic Services (MCTS) Centres broadcast marine forecasts, current wind conditions and weather bulletins in a continuous cycle on channels 21B and 83B. They also broadcast information on aids to navigation and ice conditions.

Getting on-line

Before you set out, you may want to check on-line sources for weather information. (Cellular phones are not reliable out on the water. It is best to rely on Weatheradio and marine radio services once afloat.)

Here are a few to get you started:

Environment Canada

www.weatheroffice.gc.ca
www.ec.gc.ca
www.wap.gc.ca (wireless device)

NOAA (U.S. weather services)

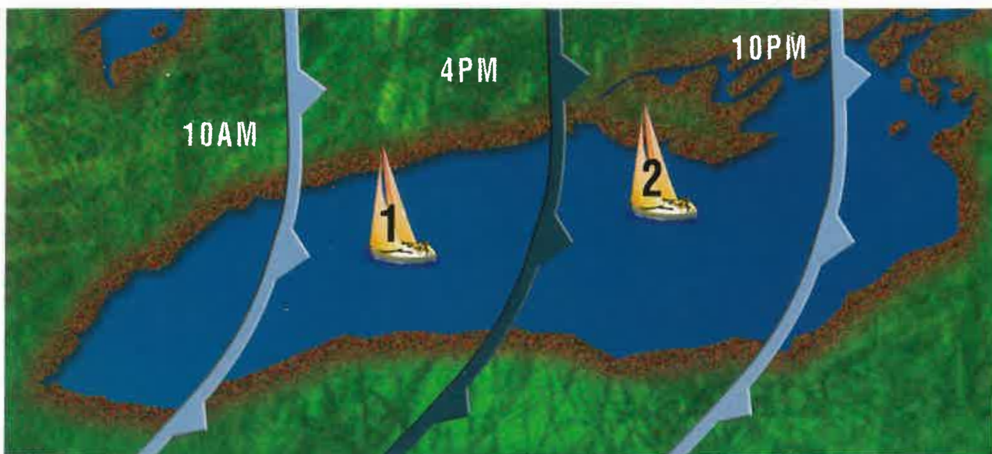
www.noaa.gov

Using the forecast

The forecasts, maps and charts that Environment Canada provides are a good starting point for anyone wanting to make sound boating decisions; but they are not enough on their own. They reflect larger patterns and are updated regularly, but they cannot be expected to represent all the local effects and variations you may encounter over time.

With the information in this guide you can start to recognize what local factors may affect nearshore weather and waves – water depths, currents, topography, traffic patterns, etc. And you can become more responsive to local signs of weather changes – signs that a weather front is slowing down or speeding up, or signs that thunderstorms or squalls are developing. (See pages 29-32 and page 76 for observers' tips.) With your newly acquired weather wisdom you can make thoughtful adjustments to the weather forecast to allow for what you know and experience locally.

It is also important to take into account where you are in relation to current and forecast weather patterns – both in time and location. Be conscious of the constraints on forecasts, which mustcover expected conditions over large lakes over a 48-hour period. Note where you are in your forecasting area and adjust the forecast to reflect your location. For example, a forecast of rain beginning in the afternoon for Lake Ontario could mean that rain will start at noon in Hamilton, but not until 6pm in Kingston. The map below demonstrates how your location in relation to the forecast will be reflected in your experience of the weather.



A cold front is projected to be in the centre of a local forecast area at 4 pm. A boater will **1** get the frontal passage around 2:00 pm, while someone at **2** can expect the front around 5-6 pm.

Ask yourself these questions

1. What is the current weather?

Listen to all the local reports for your area. Take a good look at your own wind and sky conditions.

2. Which forecast do you want?

Make sure you listen to the right forecast for your area, as well as adjacent area forecasts. When possible, also listen to forecast coming from areas west of your location, since weather generally moves in from the west.

3. What are the general features?

Consider the location of fronts, highs and lows, as described in the marine synopsis, and where they are in relation to you and your boating plans.

4. What marine warnings are in effect or forecasts?

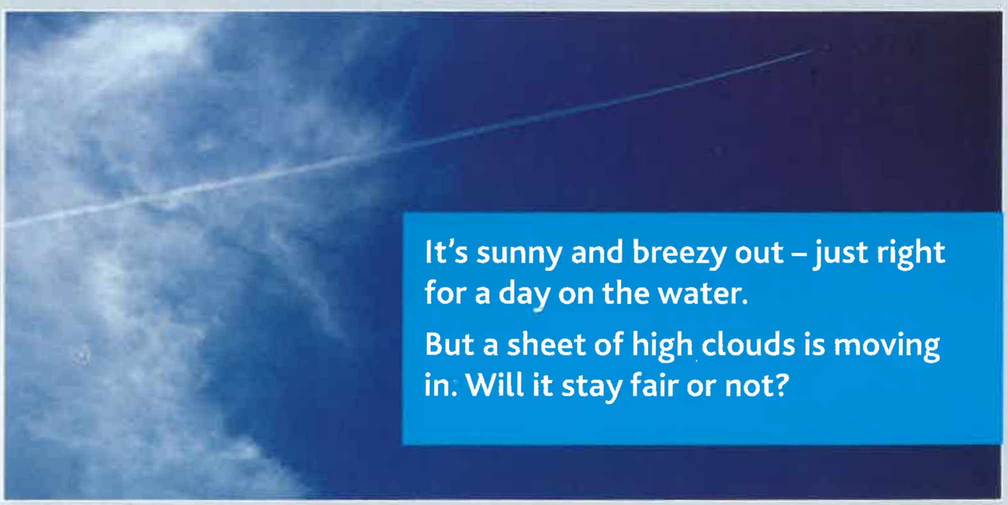
Interpret these according to the size and handling capabilities of your boat. Are there any severe weather watches or warnings in effect?

5. What is the forecast trend – worse, the same, or better?

Consider how long you will be out on the water.

6. What are your local conditions?

Assess local hazards and conditions (see *Local conditions* section), and adjust the forecast to incorporate any variations that are likely in your area.



Sources for Great Lakes weather information
Weatherradio
Weatherradio (FM)
CCG MCTS Centre
Storm Prediction Centre
Kenora (off map)
Fort Frances (off map)
Beardmore (off map)
Red Rock
Thunder Bay
Pukaskwa
Duluth
Houghton
Marquette
Montreal River
Sudbury
North Bay
Little Current
Parry Sound (88.9 FM)
Ottawa
Alpena
Cyprus Lake
(90.7 FM)
Rosseau
Orillia
Prescott
Kingston
Port Elgin
Collingwood
Peterborough
Lindsay
Watertown
Mount Forest
Toronto
Goderich
Kitchener
Rochester
St. Catharines
Sarnia
London
Buffalo
Erie
Windsor
Toledo
Cleveland

Counting strokes and flashes

Being caught in the open during a lightning storm can be a harrowing experience, but those lightning strokes and flashes can help mark the approach of storm activity. Boaters can use their eyes and ears to monitor lightning activity – watching distant flashes approaching from the west, or being alert to a build-up of static on the AM band of their radios.

And Environment Canada now has a network of new technology to help it stay on top of lightning activity across Canada – the Canadian Lightning Detection System.

Sensors record both cloud-to-ground and cloud-to-cloud lightning, counting the number of strokes per flash (there can be 1-20 lightning strokes during a single flash), measuring the voltage, and mapping out lightning data on screen within seconds (showing precisely what is happening, where and when).

This lightning detection system should prove helpful in verifying and augmenting other sources of information on threatening weather situations, especially in areas which are on the outside edge of radar coverage. The Great Lakes region is served by lightning sensors at Windsor, Owen Sound, Sault Ste. Marie, Geraldton, Pickle Lake, Red Lake and Petawawa, as well as impact sensors (which record cloud-to-ground lightning with a high degree of accuracy) at Thunder Bay and Timmins.

CONVERSION TABLES

TEMPERATURE
40°C = 104°F
35°C = 95°F
30°C = 86°F
25°C = 77°F
20°C = 68°F
15°C = 59°F
10°C = 50°F
5°C = 41°F
0 °C = 32°F
-5°C = 23°F
-10°C = 14°F
-15°C = 5°F
-20°C = -4°F
-25°C = -13°F
-30°C = -22°F
-35°C = -31°F

PRESSURE
970mb = 28.64" = 97.0kPa
975mb = 28.79" = 97.5kPa
980mb = 28.94" = 98.0kPa
985mb = 29.09" = 98.5kPa
990mb = 29.23" = 99.0kPa
995mb = 29.38" = 99.5kPa
1000mb = 29.53" = 100.0kPa
1005mb = 29.68" = 100.5kPa
1010mb = 29.83" = 101.0kPa
1015mb = 29.97" = 101.5kPa
1020mb = 30.12" = 102.0kPa
1025mb = 30.27" = 102.5kPa
1030mb = 30.42" = 103.0kPa
1035mb = 30.56" = 103.5kPa
1040mb = 30.71" = 104.0kPa
1050mb = 31.01" = 105.0kPa

WAVE HEIGHT
0.5 m = 2 ft
1 m = 3 ft
1.5 m = 5 ft
2 m = 7 ft
2.5 m = 8 ft
3 m = 10 ft
3.5 m = 12 ft
4 m = 13 ft
5 m = 16 ft
6 m = 20 ft
7 m = 23 ft
8 m = 26 ft
9 m = 30 ft
10 m = 33 ft
11 m = 36 ft.
12 m = 39 ft.

WIND SPEED

speed	knots	miles/hour	kilometres/hour
	10 kts	12 mph	19 km/h
	20 kts	23 mph	37 km/h
	30 kts	35 mph	56 km/h
	40 kts	46 mph	74 km/h
light	1 - 14 kts	1 - 16 mph	1 - 26 km/h
moderate	15 - 19 kts	17 - 22 mph	27 - 35 km/h
strong	20 - 33 kts	23 - 38 mph	36 - 61 km/h
gale	34 - 47 kts	39 - 54 mph	62 - 86 km/h
storm	48 - 63 kts	55 - 73 mph	87 - 117 km/h

READING SUGGESTIONS

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Verkaik, Arjen and Jerrine: *Under the Whirlwind: Everything You Need to Know About Tornadoes,* Whirlwind Books, 1997. (For detailed discussion of stormy weather.)

GLOSSARY

Airmass: An extensive body of the atmosphere with comparable temperature and humidity. It may extend over an area of several million square kilometres and over a depth of several kilometres.

ATAD (Automated Telephone Answering Device): A recorded telephone message giving current and forecast weather information.

Backing: A counter-clockwise change in wind direction. For example, from southwest to southeast, through south. It is the opposite of veering wind.

Channelling: The tendency of the wind to follow the axis of a channel or be steered by sloping land, resulting in a change in its direction.

Circulation cell: A "package" of air with a distinct circulation pattern, i.e. a lake breeze.

Cliff effect: The dramatic alteration in direction of an onshore wind by a cliff face. The offshore equivalent is called the lee effect.

Cold front: A transition zone where a cold air mass advances and replaces a warm air mass.

Convection: The process whereby air rises because it is warmer (lighter) than its surroundings. Examples of convective clouds are cumulus and cumulonimbus.

Convergence (coastal): The convergence or running together of land and sea winds, creating a stronger band of wind near the shore. Factors such as the shape of the shoreline and the angle between the wind and the shore determine the severity of this effect.

Corner effects: A small-scale convergence effect that can be quite severe. It occurs around steep islands and headlands.

Cross seas: Steep waves with short, sharp wave crests. They form when two or more wave trains moving in different directions run together.

Dewpoint: The temperature to which air must be cooled, in order to become saturated by the water vapour already present in the air.

Eddy: A small rotating area of water.

Fetch: The distance wind, usually of uniform speed and direction, which blows over the water surface. Fetch length is related to the height of the wind-generated wave heights. The longer the fetch length, the higher the wind-generated wave heights.

Fog: A cloud based at the earth's surface, consisting of tiny water droplets, or under very cold conditions, ice crystals or ice fog. It is generally found in calm or low wind conditions. Under foggy conditions, visibility is reduced to less than 1 kilometre.

Front: The boundary between two different air masses. A cold front is the leading edge of an advancing cold air mass, while a warm front is the trailing edge of a retreating cold air mass.

Funnelling: The process whereby wind is forced to flow through a narrow opening between adjacent land areas, resulting in increased wind speed.

Funnel Cloud: A condensation cloud, typically funnel-shaped and extending from the base of a cumuliform cloud, associated with a rotating column of air that may or may not be in contact with the surface.

Gale: Wind speed of 34 to 47 knots inclusive; has a Beaufort wind force of 8 to 9.

Gust Front: A sharp, localized windshift line near a thunderstorm, accompanied by brief strong winds, a bank of low clouds (usually) and a temperature drop.

Gyre: A circular or spiral motion, primarily referring to currents.

High: Region of the atmosphere where the pressures are high, relative to those in the surrounding region at the same level. In the Northern Hemisphere, winds around a high move in a clockwise fashion.

Inversion: More fully known as "temperature inversion". This occurs when warm air sits over cold air, possibly trapping moisture and pollutants in the surface air layer.

Isobar: A line connecting points of equal pressure on a map.

Knot: a unit of speed equal to one nautical mile per hour (1.9 km/h).

Lake breeze/Land breeze: This coastal breeze blows from the land to the sea, lake or river, and usually occurs at night when the temperature of the water is often warmer than the nearby land. The water heats the air above, which rises and is replaced by cooler air from the land. (See also sea breeze).

Lapse rate: The rate of temperature change with height in the atmosphere (global average, 6.5ºC/km). The adiabatic lapse rate (or dry adiabatic lapse rate) is the normal rate of change (9.8ºC/km) for a dry parcel of air that is moved up or down and cools or warms as the pressure changes. The wet adiabatic lapse rate (4.9 ºC/km) is the rate at which saturated air cools as it ascends.

Lee effect: The effect of topography on winds to the lee (downwind) side of an obstacle such as a steep island or cliff.

Leeward: A term that means, "is situated away from the wind;" in other words, downwind and opposite of windward.

Low: Region of the atmosphere where the pressures are low, relative to those in the surrounding region at the same level. In the Northern Hemisphere, winds around a low move in a counter-clockwise fashion.

Marine inversion: A temperature inversion created by the cooling of a warm airmass from below by the cool lakes on spring and summer days.

Millibar: A unit for expressing the atmospheric pressure. Average global sea level pressure is about 1013 millibars (101.3 kilopascals).

Pressure: The force exerted by the weight of the atmosphere, also known as atmospheric pressure. When measured on a barometer it is referred to as barometric pressure and expressed in inches of mercury, millibars or kiloPascals.

Pressure gradient: The amount of pressure change occurring over a given distance.

Prevailing wind: A wind that consistently blows from one direction more than from any other. In this guide, "prevailing" refers to the predominant wind over a region irrespective of local effects.

Quasi-stationary: Describes a low or high pressure area or a front that is nearly stationary.

Reflection of waves: The process whereby waves bounce off a steep shoreline or structure rather than refracting or breaking, as they would in shallower waters. Reflected waves interact with oncoming waves to create confused sea conditions.

Refraction of waves: The change in the direction of movement of waves which encounter shallow water.

Ridge: An elongated atmospheric area of relatively high pressure, extending from the centre of a high pressure region; the opposite of a trough.

Riptide: Locally agitated waters caused by the interaction of currents, or by a rapid current moving over and irregular lake bottom.

Seiche: The oscillation of water in a lake that follows a wind set-up. It slowly subsides over one to two days.

Set: The direction towards which a current is headed – for example, a current moving from west to east is said to be set to east.

Set-up: The process whereby strong winds blowing down the length of a lake cause water to "pile up" at the downwind end, raising water levels there, and lowering them at the upwind end of the lake.

Shoaling: The process whereby waves coming into shallow water are slowed by bottom friction; and so the waves become closer together and steeper.

Squall: An atmospheric phenomenon characterized by an abrupt and large increase of wind speed within minutes, then suddenly diminishes. Squalls are usually associated with thunderstorms, and as such are often accompanied by heavy showers, thunder, and lightning.

Squall line: A line of thunderstorms which may run parallel to, and often ahead of, a cold front and is accompanied by sudden strong winds.

Stable: An atmospheric state with warm air above cold air, which inhibits the vertical movement of air.

Steam fog: A type of fog that forms when an outbreak of cold Arctic air settles over an expanse of open, relatively warmer water (See sea smoke, arctic sea smoke and advection fog, or sea fog).

Storm force winds: Wind speed of 48 to 63 knots inclusive, with a Beaufort wind force of 10 to 11.

Surge: The positive or negative difference in sea level from the predicted astronomical tide, due to the forces of the atmosphere. The two main atmospheric components that contribute to a storm surge are air pressure and wind.

Swell: Undulating movement of the sea surface that persists after the originating cause (wind-generated waves) of the motion has ceased.

Thunderstorm: A local storm, usually produced by a cumulonimbus cloud, and always accompanied by thunder and lightning.

Topography: The shape of the land.

Tornado: A violently rotating column of air, in contact with the surface, pendant from a cumuliform cloud, and often (but not always) visible as a funnel cloud.

Track: The path that a storm or weather system follows.

Trough: An elongated area of relatively low pressure, extending from the centre of a low pressure region. It is the opposite of a ridge.

Upwelling: The process by which cold waters from the depths of a lake rise to the surface.

Unstable: A turbulent, convective state in the atmosphere, resulting from a rapid decrease in air temperature with the altitude.

Valley winds: Valley winds encompass several effects, the first of which is the tendency of wind to funnel down a pronounced valley. The term also refers to the movement of air down the slopes of a valley at night (katabatic winds) or up the slopes of a valley during the day (anabatic winds).

Veering: A clockwise change in wind direction. For example, from southeast to southwest, through south. It is the opposite of backing wind.

Warm front: A transition zone where a cold air mass retreats and is replaced by a warm air mass.

Waterspout: Any tornado over a body of water.

Wave steepness: The ratio of wave height to wave length.

Wind waves: Waves built by the movement of wind over water.

Windshift line: A long but narrow axis across which the winds change direction (usually veer).

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Email: please go to: http://weatheroffice.gc.ca/mainmenu/contact_us_e.html

Environment Canada Environnement Canada

Safe Boating Checklist

Get Ready

Is your Boat Properly Equipped?

- ❑ One personal floatation device (e.g. life jacket) per person
- ❑ Something for bailing
- ❑ Two oarlocks and oars or, two paddles
- ❑ Fire extinguisher(s) – easily accessible
- ❑ A sound signal such a whistle or horn
- ❑ Regulation lights
- ❑ A waterproof package containing a first aid kit, a change of clothes, emergency rations, a knife and a flashlight
- ❑ An anchor and tow rope
- ❑ Other equipment you may need (depending on type of boat and trip plan): flares, marine radio, tool kit, nautical charts
- ❑ Your copies of "Wind, Weather & Waves" and the Canadian Coast Guard's "Safe Boating Guide"

Get Set

Are you prepared?

- ❑ Check the weather before leaving home, and relate it to route maps
- ❑ Write out a trip plan (when you're leaving, where you're going, when you expect to arrive) and give it to someone you trust to get help if you need it
- ❑ Dress appropriately for weather and water conditions
- ❑ Do not drink alcohol. If you have, postpone your trip
- ❑ Check local weather signs and water temperature; recheck forecast

Is your boat prepared?

- ❑ Check fuel levels – do you have enough if a storm hits?
- ❑ Check lines, anchor, pump, lights, radio, motor and safety equipment
- ❑ Check that all on board are wearing personal flotation devices
- ❑ Know your boat. Do not overload or overpower

Now that you are underway

- ❑ Keep your eye and ear to the weather: monitor forecasts, listen for radio static, watch the sky, be alert to wind and wave changes
- ❑ Head for the nearest safe anchorage or harbour if a storm threatens
- ❑ Slow down in bad weather and when making sharp turns
- ❑ Follow safe boating rules and help others in distress

Canada