THIS BOOK IS GOLD DUST FOR SAILORS

Will there be a sea breeze today?
Will one side of the course have better wind?
Will the wind shift during the race?

For nearly 20 years Wind Strategy has given sailors the answers to these questions and many more. It gives a set of basic principles so that you can predict the wind's behaviour virtually anywhere in the world. It shows how the wind will shift and bend over the relatively small area of the racecourse, and how it is modified by:

- the sea breeze
- the land breeze
- gusts
- clouds
- cliffs
- other boats
- islands
- the shore
- currents
- water temperature

The book also gives specific wind advice for over 20 popular venues, from the Solent to Sydney.

In short, **Wind Strategy** gives you the "local knowledge" you need to become a winner.

The Authors David Houghton spent 34 years forecasting and researching at the Met Office, and for over 30 years he has served as a Coach/Adviser to Olympic, Admiral's Cup, America's Cup and Round the World race teams. Co-author Fiona Campbell is also a professional meteorologist and was met adviser to the British team at the Athens Olympics. Both David and Fiona are keen sailors as well as meteorologists, so the book has a sharp focus on what the racing sailor needs to know.

Recommended for all racing sailors

For large-scale wind patterns see the companion volume **Weather at Sea**, also by David Houghton.

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THIRD EDITION
FOR NORTHERN AND SOUTHERN HEMISPHERES

How to predict the wind on any racecourse
Analysis of popular venues
Summary sheets to take afloat

Wind Strategy

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David Houghton
Fiona Campbell

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Contents

Preface to the Third Edition

Since writing the first edition of this book some 20 years ago, my experience with successive Olympic, Admiral's Cup, America's Cup, Whitbread and sundry other campaigns, along with on-site application of the principles to ocean and inshore racing at places such as Auckland, Barcelona, Dublin Bay, Fremantle, Hyeres, Medemblik, Palma and Sydney has provided the wherewithal to hone and refine the concepts, arguments and rules of thumb presented. Dialogue with the sailors has contributed greatly to an understanding of the bends and shifts which they have observed, and the use of this information by The Met Office in the development of their meso-scale model has provided an independent assessment of the validity of some of the arguments. My dialogue with Mike Cullen, one time Director of Research, has been particularly helpful.

Major changes in this the third edition are:

Illustrations in full colour

New chapters on 'Dangerous waves' and 'Light airs'

Detailed analysis of winds experienced at 25 of the most popular sailing venues and coastal passages including Athens and Valencia.

A substantial rewrite of about 40% of the book

The most significant change however is the inclusion as co-author of Fiona Campbell. Fiona, an experienced sailor hailing from the Isle of Skye, has picked up the baton of meteorologist to our top sailing teams, including GBR Challenge and the RYA Olympic Sailing Team. A graduate in meteorology from the University of Reading, her degree thesis was based on a study of winds in the Hauraki Gulf, New Zealand.

We have still managed to avoid mathematical equations. The presentation of wind behaviour and evolution uses conceptual models, most of them very simple, which every sailor should be able to relate to personal experience on the water, and thus achieve an immediate advantage over competitors who rely on local weather lore and undigested statistics. That's Wind Strategy!

1 The wind-wise sailor

It has for long been assumed that a helmsman competing on home waters has an advantage over the visitor because years of practice have imparted a 'seat of the pants' appreciation of the behaviour of the local wind. The confidence of the 'seat of the pants' sailor rests in the past. Every decision about a windshift is based on the argument 'it happened last time', or ' in the same month X years ago'. The confidence of the wind wise sailor, on the other hand, rests in an appreciation of the causes of bends and bands in the wind whereby accumulated experience at a variety of venues increases racing skill. Because the weather demonstrates an almost infinite number of variations, there will inevitably be occasions when the seat of the pants sailor is caught out, having 'never seen anything like it before'. The wind wise sailor however will identify a reason for the unusual event and is likely to sail better through making well-founded decisions. To be right every time is hardly possible, but knowledge increases with every new observation as new pieces are added to the total picture of weather wisdom.

Although every sailing venue is different, the forces which create and control the wind are in principle the same everywhere. There is a scientific reason for every windshift and bend, and virtually all those which are important to the racing sailor can be understood by the application of basic and straightforward principles of meteorology. Taking a laptop in a racing dinghy is not an option, and numerical modelling of mesoscale wind systems in support of dinghy racing is little short of taking a sledgehammer to crack a nut.

The best and only realistic solution is the development of simple conceptual models of wind behaviour such that every reasonably intelligent sailor can recognise what is happening while racing, identify the causes of the wind patterns experienced and make intelligent on-the-water decisions.

Similarly with clouds: there are very many variations on the theme of lines and bands of cloud, and indeed great artists have for centuries found them a never-ending source of inspiration. For the sailor every cloud and every cloud pattern conveys a message of some sort concerning the origin, movement, and stability of the air it represents. Chapter 14 looks at the messages which are capable of translation into tactical advice.

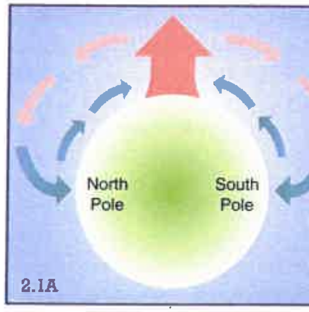
National Meteorological Services do not normally make detailed wind observations in coastal waters. It is far too expensive. By and large the only observers are sailors, and it is their observations reported following a day's racing, in their logbook or by word of mouth, that have been the mainstay of this study. One might have thought that the picture would become more and more complex over the years, but the opposite has been the case; a handful of basic principles has emerged which are applicable to understanding the behaviour of the wind virtually anywhere in the world. The following chapters are a result of some 40 years of study of sailing venues all over the world, working closely with sailors involved in world-class racing from round the buoys to round the world events. Most of the basic principles are presented in terms of simple conceptual models of wind behaviour. The principles are the same in both hemispheres but the rules of thumb differ along with the geometry of the model illustrations. So the main arguments are developed for the Northern Hemisphere, followed by a couple of chapters summarising the differences which apply for the Southern Hemisphere.

Large scale weather systems are explained in David Houghton's *Weather at Sea*, also published by Fernhurst Books, which includes guidance to the understanding, interpretation and construction of weather maps. You need a weather map to give an overall picture of what the gradient wind is doing and what changes are expected; a first and essential stage in deducing the finer details of what to expect during a race.

2 The sailor's wind

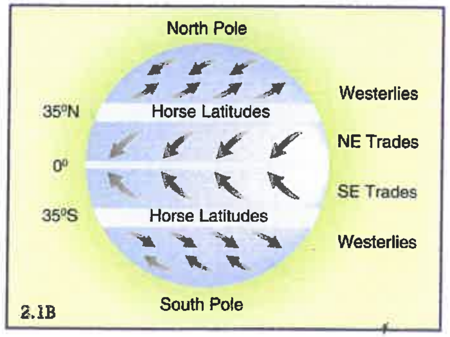
Anything moving requires energy to start it off, and in most cases to keep it going. The wind is no exception. Air moves around the world in response to heating by the sun. Equatorial regions receive the most heat, polar regions the least. The major wind systems of the world are all the result of heated air rising over equatorial regions and being replaced by colder air from polar regions. The zone where the major cold and warm winds meet is commonly known as the polar front, and is the birthplace of many of the larger weather systems, the depressions and anticyclones, of temperate latitudes.

The traditional, and easiest way to map the movements of air around the world is to plot the values of pressure, or weight of air, at the earth's surface. Such weather maps with their lines of equal pressure – isobars - have been in use for over a hundred years, ever since the invention of the electric telegraph. More recently, weather satellites have provided pictorial evidence of the size, shape and main characteristics of depressions and anticyclones, the clouds acting as dye in the air to map out their development and decay.



Heated air rises over the equator, to be replaced by cooler air from the poles. Due to land and the earth's rotation, this simple model is modified as shown in the second diagram

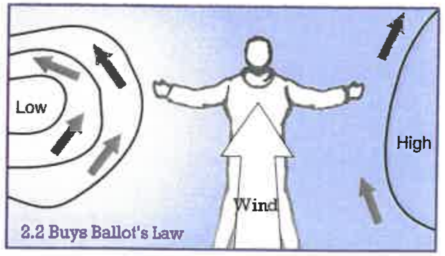
2.1A



2.1B

THE PRESSURE GRADIENT WIND

To map the winds over an area of hundreds of kilometres there is still no substitute for the surface pressure pattern, because there is a direct relationship between the wind and the gradient of surface pressure. Wherever there is a pressure gradient a wind blows with a strength directly proportional to that gradient. If the earth was not rotating, the wind would blow straight across from high pressure to low pressure – as you might expect. But because of the earth's rotation it blows across the pressure gradient, (except near the equator), one way in the Northern Hemisphere, and the other way in the



2.2 Buys Ballot's Law

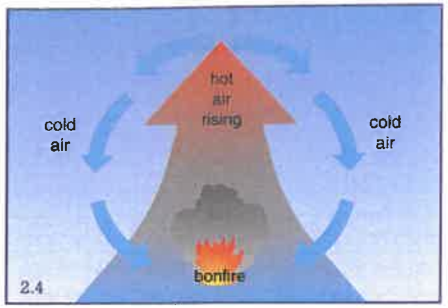
Southern. You can best remember which way using Buy's Ballots Law which states that in the Northern Hemisphere, if you stand with your back to the wind the low pressure is on your left-hand side (Figure 2.2).

To enable the sailor to take full advantage of this relationship between pressure gradient and wind, many weather maps are printed with a scale in one corner called the 'geostrophic scale'. Figure 2.3 is an example. Take a pair of dividers, set the points at right angles to adjacent isobars over the area of interest, then transfer their distance apart to read (on the scale) the wind speed for the appropriate latitude. Note that for a given isobar spacing the wind is much stronger in low latitudes than in high latitudes.

For a more detailed introduction to weather maps, weather systems and the pressure gradient wind including the all-important Earth-turning (Coriolis) Force, see the companion book *Weather at Sea*.

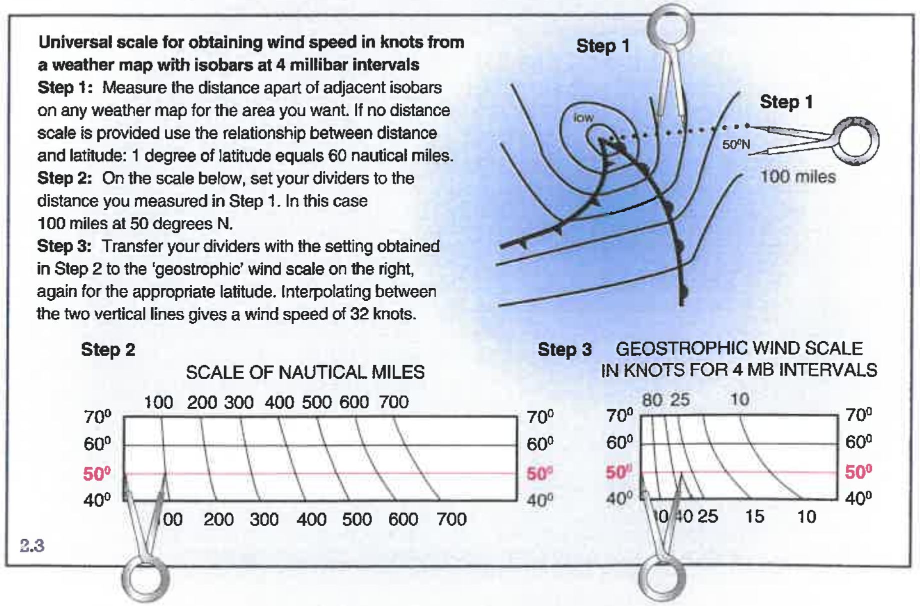
Local winds

The global picture of the creation, movement and interaction of warm and cold air masses



2.4

is repeated on virtually every space scale down to that of the garden bonfire, where the hot air carries the smoke upwards and is replaced by colder air moving in around the sides (figure 2.4). This essentially simple picture of air movement into and upwards from a bonfire typifies what happens continually all over the world. Variations in heating and cooling of the land and sea due to variations in cloudiness, topography, time of day, colour of the land, angle of the sun, etc, all feature in the production of local winds. Thinking about the pattern of air movement around a fire will help you tune into the air movements due to temperature



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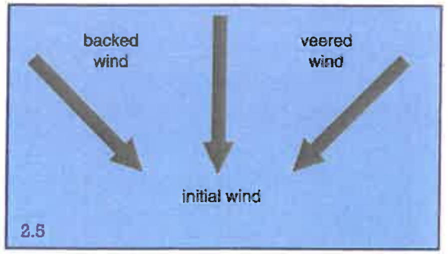

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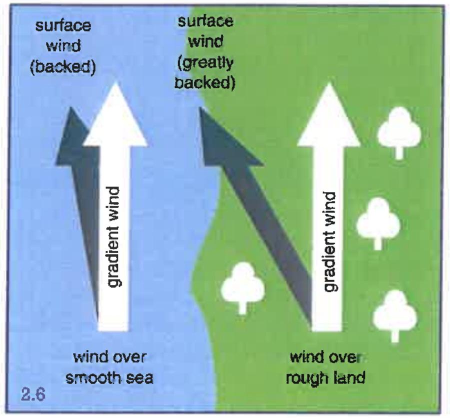
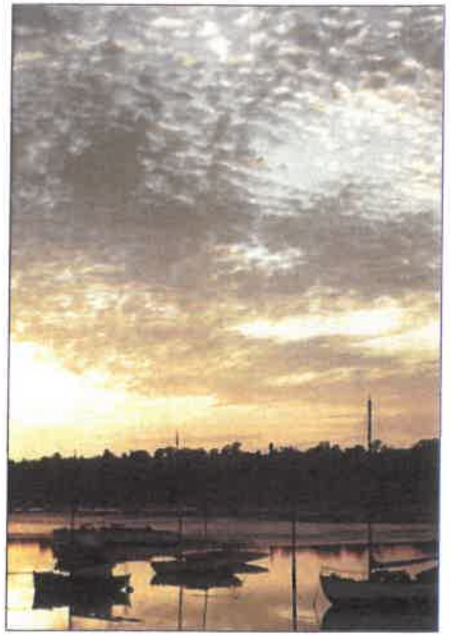


2.6

differences between land and sea or between one side of a valley and another – changing as the sun moves round. You can also contemplate the airflow into and out of a typical cumulus cloud, and the origins of the gusts and lulls in the wind to which we constantly have to tack. You may also be able to make a reasonable shot at predicting the onset of a new breeze, or the next stage in the evolution of the one you have got. The purpose of this book is to make you a wind-wise sailor, capable of the best-possible decision at every stage of a race.

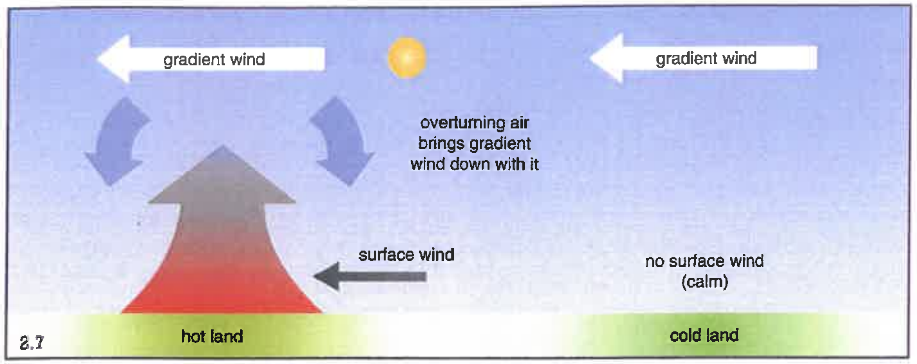
Drag and stability

We have mentioned how the pressure gradient drives the wind, and that this pressure gradient wind is found at a height of about 500 metres, above the influence of surface drag or friction. We have also seen how air warmed at the ground rises to be replaced by colder air from aloft. The extent


Wind dying as the sun sets and the land cools: altocumulus above.

to which this happens depends upon the stability or buoyancy of the air which strongly influences the ability of the wind to overcome surface friction. Let's look at these factors in turn.

Drag The rougher the surface the greater the drag. A smooth sea exerts minimum drag, a forest gives near maximum drag. Drag influences the speed of the wind: the greater the drag the slower the wind for a given pressure gradient. It also influences the wind direction, backing the wind from the pressure gradient direction in the Northern Hemisphere and veering it in the Southern Hemisphere. Backing means the wind direction swings anticlockwise, veering means the change is clockwise. (Figure 2.5). Over a smooth sea the surface wind is only about 15 degrees back from the wind at 500 metres. Over a forest the difference may be 40 degrees or even more (Figure 2.6).

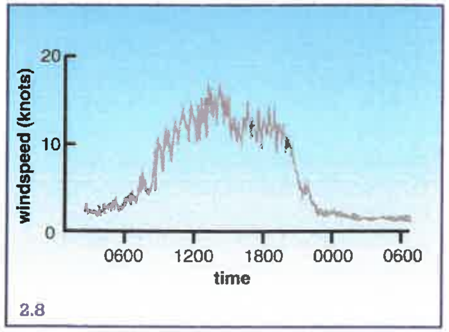


2.7

A modern town with a variety of high rise buildings presents obstacles to the wind rather than a simple friction effect. These are discussed in Chapter 16.

Stability The critical factor in determining the stability of the air at ground or sea level is the temperature of the surface. To overcome drag there has to be a continual transfer of momentum downwards. This process is seriously hindered when the air is stable, and encouraged when it is unstable (buoyant). Air that is warmed at the earth's surface becomes unstable and rises to be replaced by colder air from above. Air that is cooled at the earth's surface becomes stable and resists any attempt to make it rise. Unstable air is continually overturning and transferring momentum downwards, minimising the effect of surface friction. In stable air there is little interaction between the air near the surface and the air higher up, merely the drag of the air on itself, which is often insufficient to keep it going at the surface, so that frequently the air near the ground stops moving altogether (Figure 2.7).

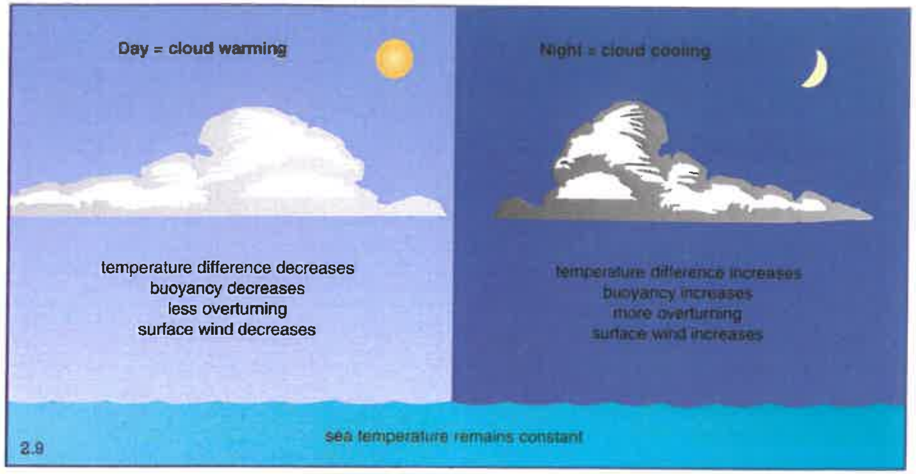
The visibility is a good indicator of how well the air is mixed by overturning. In unstable air visibility is typically good. In stable air pollution is trapped near the ground and it is typically hazy with poor visibility.



2.8

Change in wind between day and night over land

Over land the rise and fall in temperature between day and night causes changes, often major changes, in the wind. There are of course sea breezes and land breezes which we will consider in later chapters. But aside from these the mere change in surface temperature means a change in wind as the air near the ground goes through a diurnal cycle of heating and cooling. From sunrise through to mid-afternoon the air near the ground becomes increasingly unstable, and as the downward transfer of momentum increases so the wind increases. As the sun goes down the temperature falls and the wind decreases. After dusk if there is little or no cloud the surface temperature falls quickly, the air becomes very stable and the surface wind soon dies. Figure 2.8 is a typical record of windspeed over 24 hours due solely to the rise and fall in temperature as



2.9

the sun rises and sets. These considerations are as important for inland sailors as for those on coastal waters. The wind strength over a small lake is largely determined by what happens over the land around. Near coasts the influence of the changing land temperature is particularly noticeable when the gradient wind is blowing offshore.

If the wind is strong – 25 to 30 knots or more – there is usually enough mechanical turbulence to keep the air well-mixed and maintain a downward transfer of momentum throughout the night as well as the day. This effectively prevents not only a fall in temperature at night but also a rise by day, and the wind is more constant.

On occasions when the wind dies away at night and cold stable air becomes established near the surface over land, it can be difficult to shift. Where the cold stable air is protected by hills from the wind above, for instance in a deep valley, it can persist for several days or until cloud and rain arrive to help move it.

Change in wind between day and night over the sea

At sea the surface temperature varies little from day to night – a degree or two at most – since the specific heat of water is much greater than that of land and also because mixing is fairly continuous. In many places the largest variations in sea surface temperature over a period of a few hours are associated with tidal movements.

Under skies covered in low cloud, however, a significant change in wind between day and night is experienced due to the rise and fall in temperature of the top of the low cloud. Under persistent low cloud the sea surface temperature remains constant; there is no sun to warm it and no clear sky at night to allow it to cool. But the top of the cloud will warm by day and cool at night. The colder the cloud top the greater the temperature drop from the sea surface to the top of the cloud, so the more unstable the air and the stronger the wind. The warmer the cloud top the smaller the temperature drop from the surface, so the more stable the air and the lighter the wind (Figure 2.9). Thus we have a reversal of the typical diurnal variation in wind over land with the strongest wind in the early hours and the lightest in mid-afternoon. A good example is found offshore at San Diego where over a cold sea we find a persistent layer of stratocumulus cloud with the average wind varying from about 13 knots in the early morning to 6 to 8 knots in the afternoon.

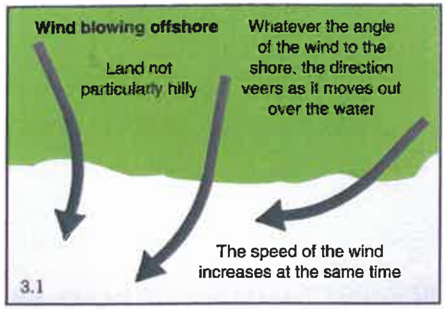
3 Wind facts – coasts, islands, lakes

This section is entitled 'Wind Facts' because it describes bends and bands in the wind which are always present to some extent. They do not depend on the weather forecast and the standard forecast does not include this sort of detail. They depend only on the orientation of the wind in relation to the land, its topography and the stability of the air, details which you normally have to sort out for yourself.

Let us look first at the influence of the coast on the wind, depending on whether it is blowing off, along, or onto the shore. To start with let's assume a coastline (any coastline of sea or lake) which is straight, fronting land which is not particularly hilly; no cliffs, no mountains within a few kilometres of the coast, and no islands within at least 20 kilometres. The coast can however be facing in any direction in the Northern Hemisphere – see chapter 6 for the Southern Hemisphere.

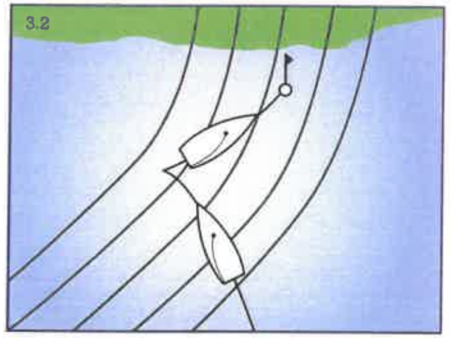
Wind blowing off the shore

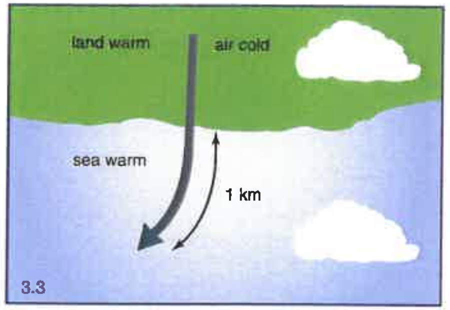
Some books state incorrectly that a wind blowing off the land always changes direction towards a line at right angles to the land, wrongly assuming that this is a case of refraction. This is not so. The wind does not move from one medium to another, it is simply subject to less drag as it moves out over the water. We saw in Chapter 2 that the direction of the surface wind over land is about 40 degrees back from the gradient wind direction, while over the water it is only about 15 degrees back from the gradient. So whatever the angle of the wind to the shore, the direction of the wind must veer as it moves out over the water (Figure 3.1). This veer is fairly gradual over a distance of from 1km to 5km downwind from the shore, a

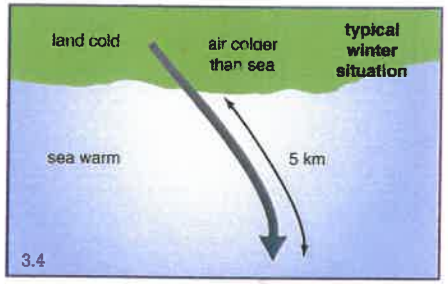


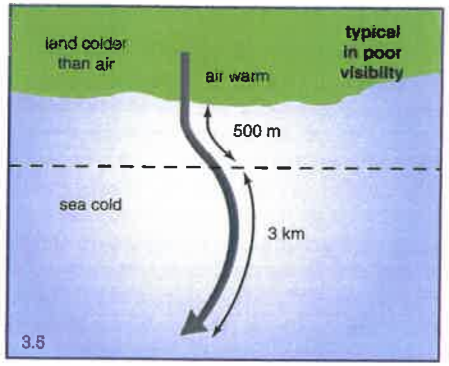
distance which depends on the stability of the air. The speed of the wind increases at the same time, the moving air adjusting to the decrease in frictional drag over the water. The direction and speed we are talking about are the average direction and speed, made up of gusts and lulls and everything in between. The changes in the character of the gusts and lulls are discussed in Chapter 5. An important point to note here is that the change in wind direction is most marked in the lulls. Note also that 'downwind from the shore' is not the same as seaward – i.e. at right angles – from the shore. If the angle of the wind to the shoreline is small the change in direction and speed will be achieved within a much smaller distance seaward from the shore than in the case of a wind at right angles to the shore.

In terms of tactics, if you are beating towards a mark, which is within 4 or 5 kilometres downwind from the shore, you can expect port tack to pay (Figure 3.2). The nearer you are to the coast the larger the bend in the wind. But a bend of some 20 to 30 degrees is massive and 4 to 5 kilometres is a long way, and fortunately it is possible to obtain more precise guidance by looking at









the stability of the air in relation to the land and sea surface temperatures as follows:

If the air is cold and the sea and land are relatively warm (typically with cumulus clouds over both land and sea) the air is unstable to the temperatures of both land and sea surfaces and the veer in wind direction will be completed in a distance of about one kilometre downwind from the shore (Figure 3.3).

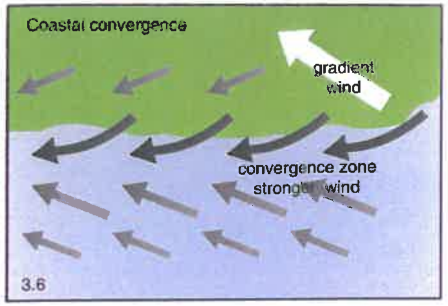
If the land is cold, the sea warm, and the air relatively cold (a typical winter situation) the stability decreases as the air moves out over the water, thermally induced mixing gets going and the veer is likely to be completed in a distance of 3 to 5 kilometres downwind (Figure 3.4).

If the air is stable, that is, warm relative to both the land and sea temperatures the change in direction as the wind leaves the land takes longer and is unlikely to be completed in less than 5 or 6 kilometres downwind.

Just occasionally, when the air is very stable, the veer as the air leaves the shore is preceded by a sudden, and short-lived back (Figure 3.5). This occurs when the water is relatively cold, typically in poor visibility. The air then starts to slide towards low pressure as it leaves the land, almost as though it is forgetting about Coriolis Force. The back is likely to be more noticeable at masthead height than lower down.

Wind blowing along the shore

With a wind blowing parallel or nearly parallel to the coast there is a major difference in wind within about 10 kilometres of the shore depending on whether the land is on your right or left hand when facing into the wind. You will see from Figure 3.6 that with the land on your left the different angles of the surface winds over land and sea are convergent for the same pressure gradient wind, resulting in a band of stronger wind near the shore. The increase in wind speed in



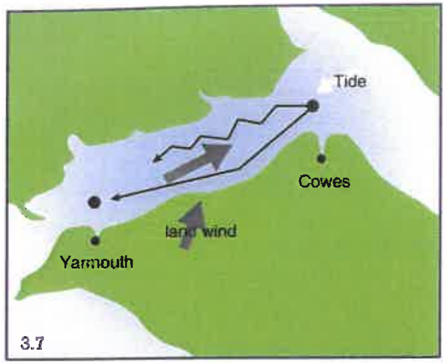
3.6

the band is in the order of 25%, e.g. 5 knots added to a 20 knot wind. The converging airstreams often give more cloud near the coast, sometimes enough to produce a shower or two.

There is no precise figure for the distance from the shore of the strongest wind. On a straight coast it is generally between 2 and 5 kilometres off. On an irregular coast the wind will blow so as to smooth out the irreglarities, sometimes strongest close inshore, sometimes strongest further out. In the case of headlands separated by a shallow bay, the band of strong wind will extend from headland to headland, being close inshore at each headland.

The stronger wind just offshore is sometimes mistaken for a sea breeze. In a recent race in the English Channel some boats headed out to sea off Brighton as dusk approached, assuming that the wind inshore would die away - only to find that those that stayed 2 to 3 kilometres off benefited from an extra few knots of easterly wind all night.

If you are racing in a wind aligned in this way to the coast you can be reasonably sure not only of finding a strong wind band but also that it will remain in the same place throughout the race. Do not overlook the possible benefit of using the more backed, though lighter wind close to the shore where it will be coming off the land. When racing in the west Solent for instance in a south-westerly it is sometimes preferable to make Yarmouth Buoy on a single tack close inshore (Figure 3.7) rather than opting for a



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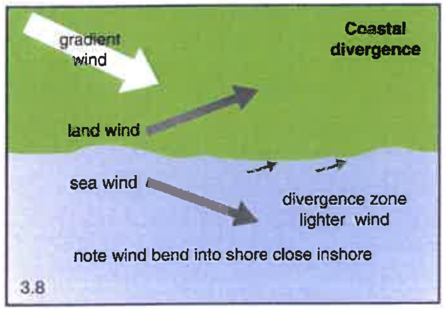


3.8

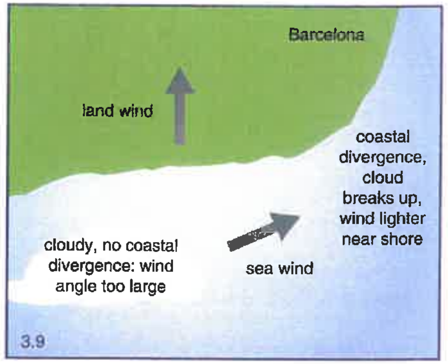
favourable tide a kilometre further off and a series of short tacks in a more veered wind.

In the opposite case of the land on your right looking upwind the two airstreams diverge (Figure 3.8) and the wind is generally lighter within a few kilometres of the shore. Because of this divergence the air tends to subside near the coast, and this clears, or at least thins any low cloud which might be around. This is why the sunniest seaside resorts are often found where the prevailing wind is westerly on a south-facing coast, easterly on a north-facing coast and so on. The reduction in wind speed may be as much as 25% compared to further offshore, but the position of the zone of lightest wind in relation to the coast is rarely as clearly defined as in the case of the stronger wind in converging airstreams.

In the afternoon, particularly from late spring to early autumn, the reduction in wind due to coastal divergence is often cancelled out by thermal enhancement of the wind near the coast (see chapter 7). When racing at any other time of day this light-wind zone is normally to be avoided, though you may want to consider using a bend of up to 10 degrees or so towards the land which may be found close inshore (Figure 3.8), and is a consequence of the more backed wind over the land dragging air in from over the water.

Where a coastline lies roughly east-west, as for instance the south coast of England, coastal divergence is found with high pressure to the south, and a feature of high pressure is that the closer you are to the high the slacker the gradient and the lighter the wind. So faced with the prospect of lighter winds near the coast due to coastal divergence, and lighter winds further away from the coast as you approach the centre of the high or the axis of the ridge, you have to judge where you are likely to find the best wind. As a general rule it is likely to be just to seaward of the coastal divergence, i.e. roughly about 10 kilometres off.

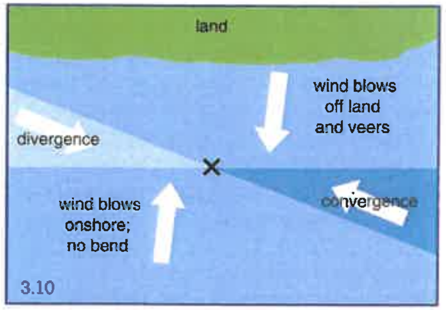
An interesting example of what happens at a bend in the coast was observed during the pre-Olympics at Barcelona in 1991. The wind was from 205 degrees true and, away to the southwest of Barcelona where the coast lies along 245 degrees, there was a full cover of stratocumulus cloud at a height of about 500 metres. Some 7 kilometres southwest of the city, where the coast bends to a new angle of about 210 degrees, the cloud started to break up and by the time the wind reached Barcelona the skies were clear. The reason for the cloud clearance was that when, as the coast curved, the angle it made with the wind direction reduced to 20 degrees, the land and sea wind streamlines started diverging so that subsidence was induced near the shore and the cloud cleared (Figure 3.9). For the sailor the change from cloudy to clear conveyed a message about the wind near the coast: 'Do not expect any variation in wind speed where it is cloudy, but look for a zone of lighter wind along the section of coast where the cloud has cleared'.



3.9

Wind blowing onto the shore

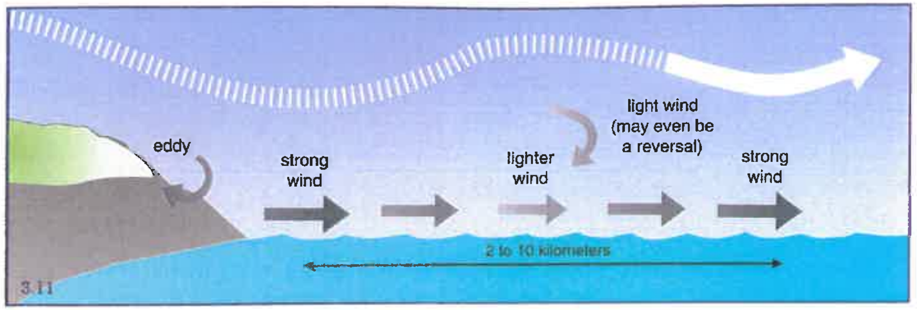
In this situation there is no significant variation in the wind strength or direction over the water as a result of the wind alignment to the shore. All the changes occur over the land. However do not overlook the thermal effects created by the heating of the land in the afternoon, which are described in Chapter 9.



3.10

Summary

Figure 3.10 summarises the influence of the land on winds over the adjacent water. Wind directions are those over the water relevant to point X, the land being aligned as at the top of the diagram. The divisions between the zones of convergence and divergence will depend on whether or not the shoreline is reasonably straight. We shall see in Chapter 8 that these direction zones are also important in judging the likely development of the sea breeze.



3.11

Tactics

If you are looking for wind, then with the wind blowing along the shore, a course set within 10 kilometres of a straight coast and no overriding influence such as a sea breeze, you should stand well in or well off – depending on the wind direction in relation to the coastline.

COASTAL CLIFFS

Wind blowing along the shore

If the wind is blowing along the coast and it is fairly straight, it makes little difference whether there are cliffs or not; we experience within a few kilometres of the coast a zone of stronger or lighter winds depending upon the wind direction. In the case of coastal convergence the strong wind band will be fairly close to the cliffs.

Wind blowing off the shore

Things are rather different with the wind blowing off coastal cliffs. There is still the same veer in direction between the wind over the land and the wind well out to sea, but for at least 2 to 10 kilometres downwind (depending on the height of the cliffs) there may be standing waves and turbulence.

Standing waves form in the wind downwind of the cliff face (Figure 3.11) when the air is stable or reasonably so, and they give relatively static zones of stronger and lighter wind, sometimes marked by a cloud sitting on top of one or more of the lighter wind zones. The zones of stronger wind are the more reliable and are likely to remain in nearly the same place for as long as the wind direction and stability of the airstream do not change, i.e. you can often expect them to stay put for the duration of a race. The zones of lighter wind may be characterised by considerable variations – even reverses in wind direction, particularly downwind of the higher cliffs, but the zones themselves are likely to stay put for some time. By careful steering you may be able to stay within a favourable zone, particularly when reaching parallel to a cliff.

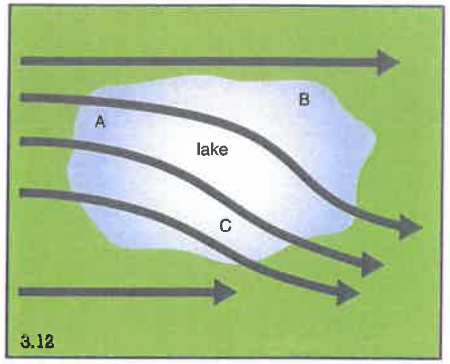
Beneath the cliff itself there is usually a large eddy with a complete reversal in wind direction.

Wind blowing onto the shore

When the wind is blowing on to the shore expect a good deal of turbulence close to the cliff itself. It is advisable to keep fairly well away from the cliff face. In a sea breeze situation (see Chapter 7) expect to find the sea breeze steered into the nearest valley or break in the cliffs, depending on how high they are, i.e. the breeze blowing along the cliff face until it finds an easier route into the land.

LAKES

The pattern of shore effects on the wind follows all the principles we have just outlined. A lake in the order of a few kilometres across, such as Rutland Water, is just big enough to demonstrate all the



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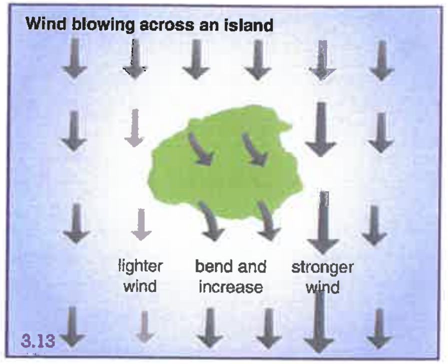


3.13

main features: a bend downwind as the wind leaves the land (side A in Figure 3.12), the coastal convergence and stronger wind where the land is on your left looking upwind (side C), and the coastal divergence and lighter conditions where the land is on the right (side B). The case of a lake (sea) breeze is described in Chapter 7.

For much larger lakes it is likely that the gradient wind will be different on different coasts, and each section of coast will have to be considered separately. In the case of lakes or fjords surrounded by mountains you will need first to consider what difference the mountains are making to the gradient wind (See Chapter 13) before applying the guidelines of Figure 3.13.

ISLANDS

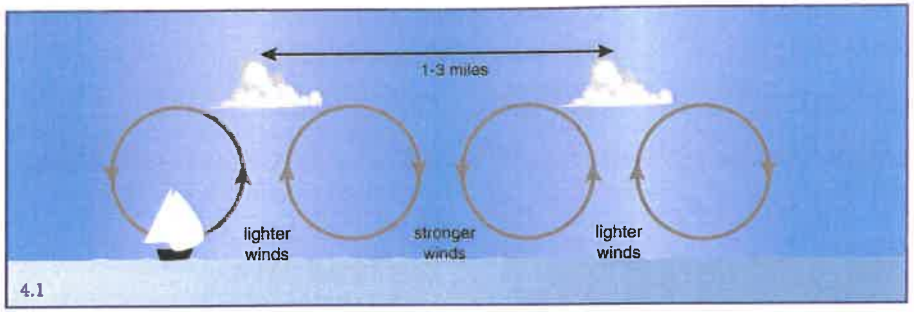
The extent to which an island interferes with the wind depends on its size and height. A fairly flat island 5 to 10 kilometres across provides a good example of the coastal influences on the wind outlined above. The air flowing over it is subject to greater friction, so it slows down and its direction backs some 15 degrees; the time and distance over which this slowing and backing takes place depends on the stability of the air and the wind speed. Adjacent to one side of the island a stronger wind will be evidence of converging airstreams, and along the other side a zone of lighter wind evidence of divergence (Figure 3.13).

Downwind features

Once a wind band has been established it is likely to continue for many kilometres downwind. It is not unusual to find a band of stronger wind 30 to 40 kilometres downwind of an island where it was generated, and a recognisable though not so clear-cut zone of lighter wind downwind from the other side. Equally a wind band generated by a protruding section of mainland coast will continue downwind and be experienced many kilometres from its source. Figure 3.13 shows how sensitive to wind direction the position of the wind band will be when some distance from where it started. This is particularly important if you are competing in a regatta where an island or coastal feature lies upwind of the racing area. You cannot take it for granted that the same side will pay every day if the wind direction is only roughly the same. It has to be identical.

The most noticeable wind features associated with mountainous islands are the vortices which are shed downwind. The Canaries are a good example. Satellite pictures often reveal vortex-shaped cloud patterns streaming up to 300 to 400 kilometres downwind from the islands, each vortex being 50 or so kilometres across.

4 Wind facts – wind bands, water temperature and tide



4.1

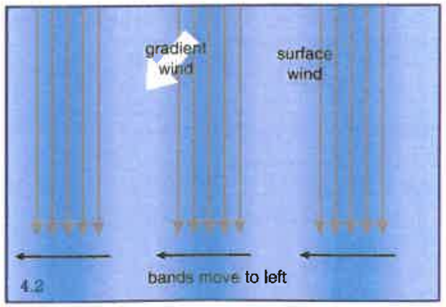
Wind bands

It is a misconception to imagine the wind being uniform for a given pressure gradient. It is not, even over a perfectly smooth sea. The wind likes blowing in bands. The most striking example of this is in the trade winds, which are characterised by lines of 'trade wind cumulus' extending over hundreds of kilometres of open ocean.

These lines of clouds are evidence of what are called 'vortex rolls' where, superimposed on the horizontal motion of the air, is a circulation in the vertical plane, air moving slowly upwards into the line of clouds and down into the clear lanes in between. The horizontal separation of the lanes is typically from 2 to 5 kilometres, and the wind is somewhat stronger in the clear lanes, where it has just come down from above, than under the clouds, where it has spent most time subject to friction near the sea surface. A cross-section is shown in Figure 4.1.

Even in the absence of cloud or beneath a uniformly grey and cloudy sky, wind bands are found wherever wind is blowing over the open sea. The difference in strength between adjacent strong and light bands may be anything from 10% to 25%, and their distance apart from 3 to 8 kilometres. Near the coast the position of the bands will normally be fixed by some feature of the coast, or even the coastline itself, particularly when the wind is blowing parallel to it. Well away from the coast the bands move slowly, driven by the component of the pressure gradient wind across them (Figure 4.2).

So, if you are sailing on the open sea, at least 10 kilometres from land, and the wind is lighter than it should be, it is advisable to sail on port tack (or gybe) until you find the stronger wind. Having found it, change to



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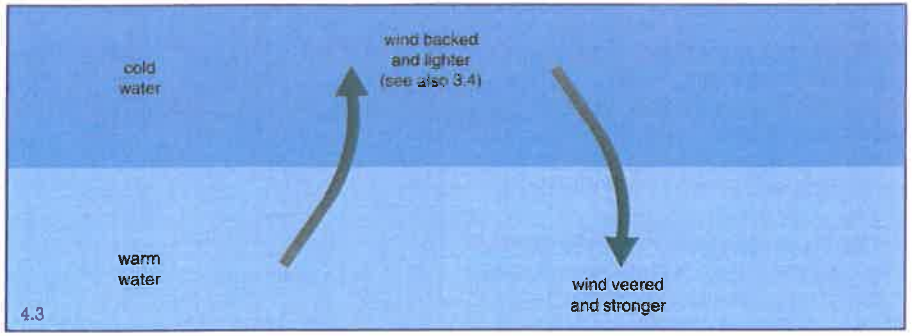


4.3

starboard tack so that you stay in the stronger wind as long as possible. Adlard Coles wrote in the 1930s that in his experience when the breeze was dying it often paid to tack onto port to find fresher winds. Now we know why!

If the gradient wind is less than about 10 knots the bands tend to deform, and sometimes large eddies 10 to 15 kilometres across appear in the wind. These 'holes' move down the gradient wind, so if you find yourself becalmed try to make way towards the gradient wind direction.

Changes in water temperature

The influence on the wind of a sudden change in water temperature is almost as significant as a coastline. Over the colder water the surface air is cooled and becomes more stable, so the effects of friction are increased and the surface air slows and backs. Conversely over the warmer water the surface air is warmed and becomes less stable. With more overturning the wind increases and veers.

The zone or dividing line between cold and warm water affects the wind almost like a coastline (Figure 4.3) with a bend in the wind direction as it crosses the boundary, the bend always on the side downwind from the transition. For winds blowing along the transition a zone of convergence and stronger winds - or divergence and lighter winds - is found, depending on the wind direction, corresponding to the friction effects illustrated in Figures 3.6 and 3.8.

Also the wind will be generally stronger over the warm water than over the cold. But in the case of cold water on the left – facing the wind - the strongest wind may be just on the cold side of the boundary.

If the stability of the air is critical – the air being stable to the temperature of one area of water and unstable to the temperature of the adjacent area - the differences in windspeed over the two areas could be as high as 25%, but the areas must be several kilometres across to be fully effective.

It is not uncommon to find water temperature changes in the order of 4°C or 5°C, particularly in estuaries, where the change from one type of water to another is marked by a change in colour of the water surface and a line of flotsam or water weed. Similar temperature differences may be found:

- Where there is tidal upwelling
- Where winds have been blowing onshore and dragged warm surface water towards the shore
- Where winds have been blowing offshore and pushed relatively warm surface water away from the shore so that it is replaced by colder water upwelling from below.

None of these situations is unusual. Following a day or so of offshore or onshore winds, variations in water temperature of 2°C or 3°C may be experienced over many regatta courses around Europe. If by the time of the regatta the wind has changed to an alongshore direction, the water temperature isotherms will be parallel to both the coast and the wind direction. There is then a strong likelihood that the course will straddle the isotherms with the water much warmer on one side than the other. Look for a significantly stronger wind over the warmer water. This may not be very different from the situation near a river estuary discussed below.

Small horizontal temperature differences over the water surface may not be very easy to recognise without a thermometer. And since a temperature difference of as little as 1°C between one side of a course and the other will be significant in a closely fought race, it is well worth checking beforehand. Any pool thermometer will do, preferably one with a small reservoir to avoid a change in reading as you haul the thermometer aboard.

The Tide

Changes in the tidal stream influence the wind in three ways:

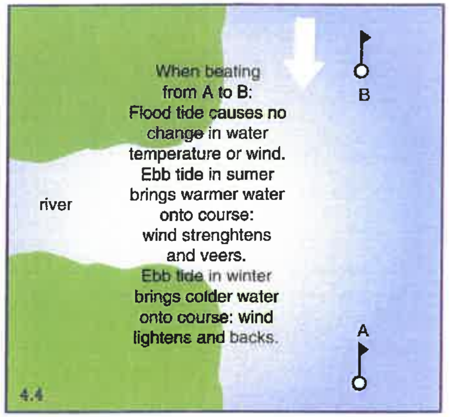
- Through change in drag on the wind
- Through change in water temperature
- Through change in the temperature of the shore.

Change in drag on the wind

This effect is easy to appreciate. When the tide is running with the wind the drag of the water on the wind is less than normal for a given wind strength, particularly since the sea will be relatively smooth and the length of the waves relatively long. A tidal stream running against the wind means a considerable increase in drag, due both to the change in relative speed and the increase in height and steepness of the waves. The actual windspeed decreases and the direction backs a few degrees.

Change in water temperature

A change in tide is often accompanied by a change in water temperature, up or down depending on whether the ebb or flood is from a warmer or colder source, or as a consequence of upwelling of colder water



4.4

from beneath. Colder water leads to colder air near the sea surface and thus increased stability, less tendency for thermally induced overturning and a lighter, more backed wind at the sea surface for a given pressure gradient wind. Warmer water leads to warmer air near the sea surface, decreased stability and a stronger, more veered wind for a given pressure gradient. So the clear message is: if you want stronger and more veered wind, sail in the warmer water; if you want lighter, more backed wind, sail in the colder water. The situation near an estuary is illustrated in Figure 4.4. If you are racing anywhere near a river estuary, think through whether you may at any time be sailing in the river water rather than sea water and what the different temperatures are likely to be, having regard to the time of year. If in doubt, take some measurements.

Change in shore temperature

The flooding by cold water of large areas of sun-heated mud flats or sand changes significantly (and often suddenly), the local sea breeze generating forces – see Chapter 7.

Changes in water temperature also influence the wind shear up the mast. This will depend on whether the water is warmer or colder than the air, and by how much. See page 77.

5 Wind facts – gusts and lulls

The wind varies on every time scale, from seconds to minutes to hours to days and even longer. It is the short period variations in the order of minutes which are normally described as gusts and lulls. Three different categories can usefully be identified:

- Gusts and lulls due to thermal overturning
- Gusts and lulls due to mechanical mixing
- Gusts and lulls inshore with an offshore wind

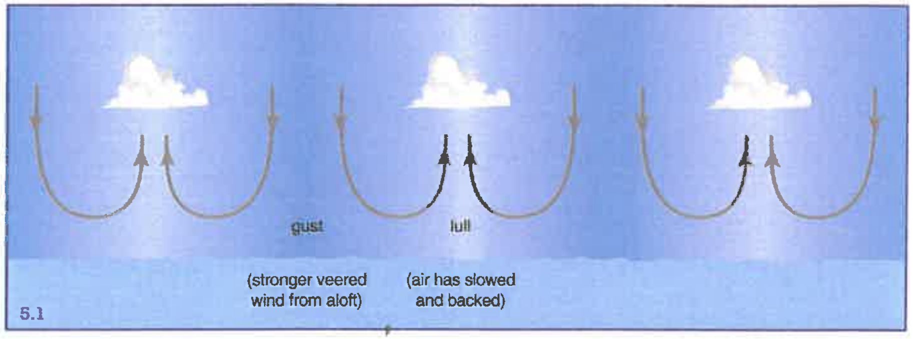
Gusts and lulls due to thermal overturning

We saw in Chapter 2 that many gusts and lulls are a result of air overturning near the sea or land surface when the air aloft, which has not been slowed or backed by friction at the surface, comes down to replace what has been subject to friction. A common cause of this overturning is thermal, when air warmed at the surface becomes buoyant, rises, and is replaced by air from aloft. This is the most easy to understand.

On many days, particularly when there is a regular pattern of cumulus clouds, the gusts and lulls arrive at fairly regular intervals. The surface wind is blowing, driven by the pressure gradient, and superimposed on it is an overturning motion, upwards underneath the cumulus clouds and downwards between them (Figure 5.1). The descending air has not experienced friction near the surface so it has approximately the horizontal speed and direction of the gradient wind. It is significantly veered and stronger than the wind which has spent some time near the surface. In other words it is a gust. The air under each cloud has spent time near the surface, has been slowed and backed by friction – it is a lull. Thermally driven gusts and lulls have one clearly defined characteristic: a gust is always veered and stronger in contrast with a lull, which is always backed and lighter.

Timescale and size of shift

If the cumulus clouds are small and relatively close together they indicate a relatively short time between gusts and lulls – perhaps 3 minutes or so. The swing in wind is typically in the order of 5 to 10 degrees in direction and 5 to 10 per cent in speed. If the clouds are larger and further apart a longer time interval is indicated – perhaps 10 to 15



5.1

minutes – and the shifts may be less regular and larger. If the convection becomes so deep that the cumulus clouds turn into cumulonimbus and showers develop, completely different wind characteristics are experienced. They are described in Chapter 14.

Gusts and lulls due to mechanical mixing

'Mechanical mixing' simply describes what happens with air moving over the earth's surface when the air is far from homogeneous and the surface is far from smooth. There is a continuous stream of fluctuations in the wind, both in speed and direction. Recordings of these fluctuations show an equal and random incidence of increases and decreases, veers and backs, with no discernable pattern of veering in gusts or backing in lulls.

Gusts and lulls inshore with an offshore wind

If the wind is blowing across the coast from land to sea you would expect that every gust would be stronger and more veered because of the lower friction over the water. And this is what sailors experience, gust and veer, lull and back going together, at least until the adaptation is complete, which may be any distance from 1 to 5 kilometres downwind from the coast, depending on the stability of the air (as we saw in Chapter 2).

Gusts and lulls at sea and near the coast with an onshore wind

Over the sea where the surface temperature is relatively uniform you will usually find fairly regular patterns in the wind which can be timed and anticipated (Figure 14.4).

The most regular of all are in the Trades, where row upon row of small cumulus clouds extend for hundreds of miles, each individual cloud indicating air rising beneath the cloud to be replaced by air moving downwards in the adjacent clear space between the clouds.

Near the coast an onshore wind brings with it all the characteristics of the open ocean.

Absence of cumulus clouds does not mean that there is no sequence of gusts and lulls. It could merely be that the air is too dry for clouds to form.

Gusts and lulls inland

Over land the pattern of gusts and lulls is usually very irregular. For one thing, the rise in temperature of the land surface depends on both its dryness and its colour, both of which vary greatly from place to place. Black tarmac for instance can easily be more than 10 °C warmer than an adjacent grass area. Sailors on small inland lakes have to take the gusts and lulls as they come, but timing the gust/lull sequence before the start of every race is still a useful practice. Some element of short period coherence is often experienced.

Does the wind always veer in a gust?

The straight answer is 'No!' Gust and veer is the pattern typically associated with cumulus clouds in the Northern Hemisphere, and you can bank on it in moderate to fresh winds when the air is unstable to the sea temperature, and also near the coast with an offshore wind. But in stable air and when the wind is strong, and also over land, do not expect any preference. And if you are beating in towards the land within 5km downwind from the coast expect the wind to back as you close the shore. An out-of-sequence backing or veering gust over the open sea may be the first indication of a new wind approaching.

Tactics

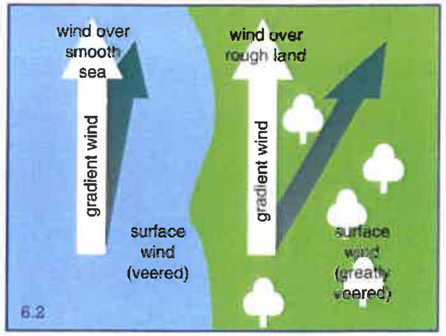
Always time the gust/lull sequence before the start of every race and note any bias towards a particular pattern.

Squalls, billows and surface gravity currents

These could all be called gusts, but they are discussed elsewhere: squalls on page 57, billows and surface gravity currents on page 54.

6 Wind facts – Southern Hemisphere

All the features of the wind described in Chapters 2, 3, 4, and 5 are experienced in the Southern Hemisphere. The arguments are virtually identical but, because the influence of the earth's rotation is reversed, the wind blows in the opposite direction relative to the pressure gradient. Many of the relevant diagrams therefore are mirror images of those for the Northern Hemisphere. The following is a summary of the facts about the wind in the same sequence as has been followed in Chapters 2 to 5.



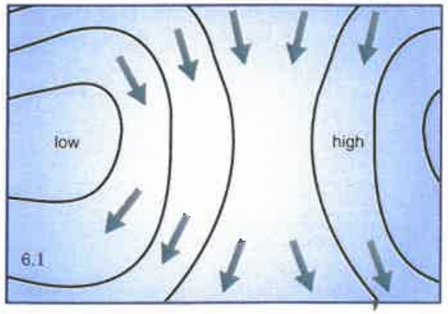
6.2

Pressure gradient and surface winds, stability and friction

There is a pressure gradient wind, which can be measured from the isobars using the same geostrophic scale (Figure 2.3). Buy's Ballot's Law for the Southern Hemisphere states that if you stand with your back to the wind, low pressure will be to your right-hand side (Figure 6.1). Because of friction the surface wind is slowed, but its direction is veered compared to the wind aloft, more so over land than over water (Figure 6.2). The temperature of the land and sea relative to the air determines the buoyancy of the air and the ability of the wind aloft to get down to the surface. There is a diurnal variation in wind between day and night. Figures 2.4, 2.7, 2.8 and 2.9 are the same for both Hemispheres. Gusts and lulls occur, and when the gusts are the result of the air aloft coming down to the surface the gust is a backed wind.

Wind blowing off the land

The only diagram in Chapter 3, which applies equally for both hemispheres, is Figure 3.11. All the others are mirrored. As a wind blowing off the land moves out over the water it backs and increases (Figure 6.3), whatever the angle of the wind to the coast. The time



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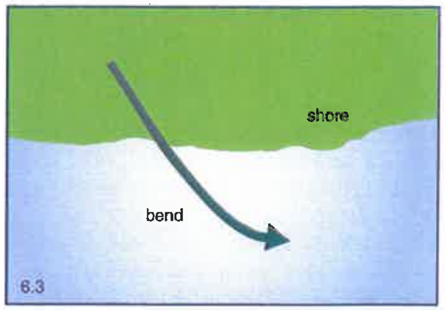
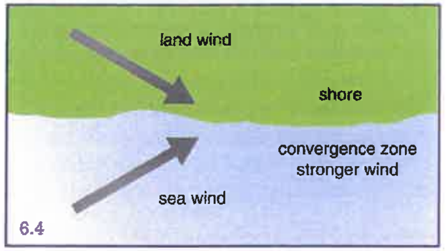


6.3

and distance downwind from the coast it takes for the new direction and speed to be fully achieved depends on the stability of the air relative to the water temperature as described on pages 14 and 15. The back is completed in about 1km downwind from the shore if the air is unstable – air cold, sea warm – and up to 5km in stable conditions – air warm, sea relatively cold.

Wind blowing along the coast

When the wind is blowing along the coast the land and sea winds either converge to give a zone of stronger winds within 1 to 5 km of the shore when the land is to your right looking upwind, or diverge to give a zone of lighter winds within 1 to 5 km of the shore when the land is to your left (Figures 6.4, 6.5). In the latter case a bend towards the shore is likely very close in. Figure 6.8 is summary.



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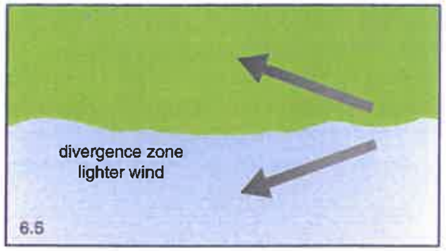
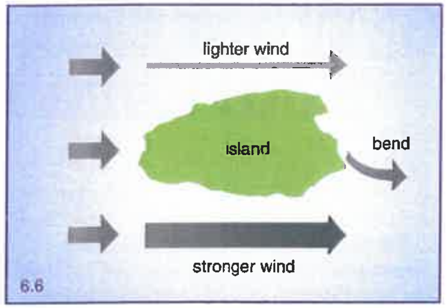


6.5

Islands and lakes

An island or a lake 5 to 6 km across provides an illustration of all the main features of bends and bands in the wind due to the differing frictional forces over land and sea (Figures 6.6 and 6.7). A wind blowing over an island at least 5km across is slowed and veered to give zones of convergence and divergence on opposite sides of the island, and a bend as the wind leaves the island. The bands of stronger and lighter wind often extend many kilometres downwind from the island.

Over a lake there is a back in direction downwind from the shore (A), a stronger wind on the right hand shore looking upwind (C), and a lighter wind on the left-hand shore (B). In the case of a small lake, 5 to 8 km across, you have to go to the downwind end



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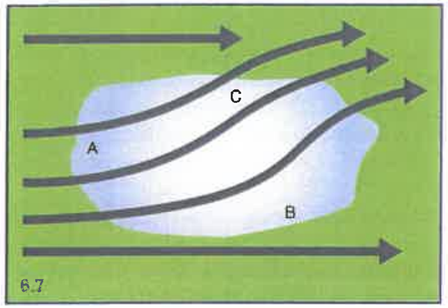

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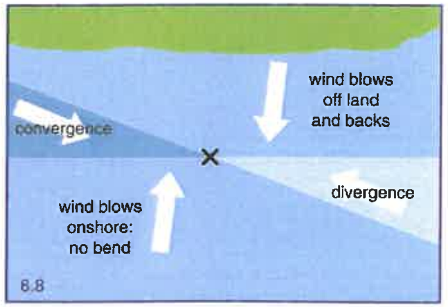

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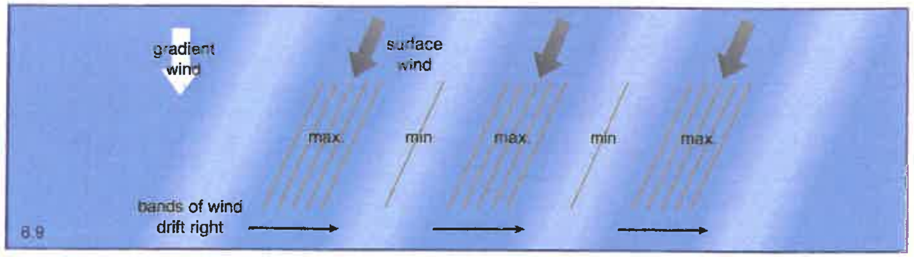

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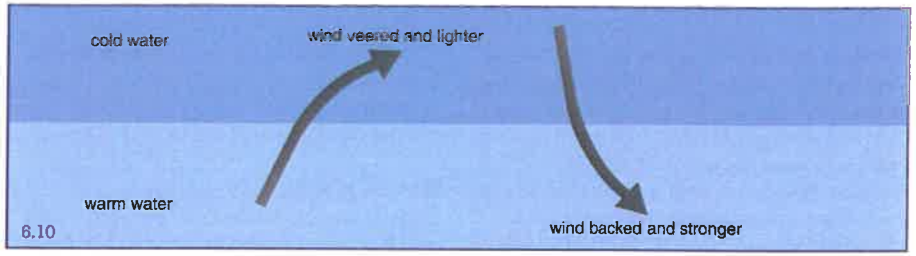


6.10

to experience the maximum effect.

The open sea

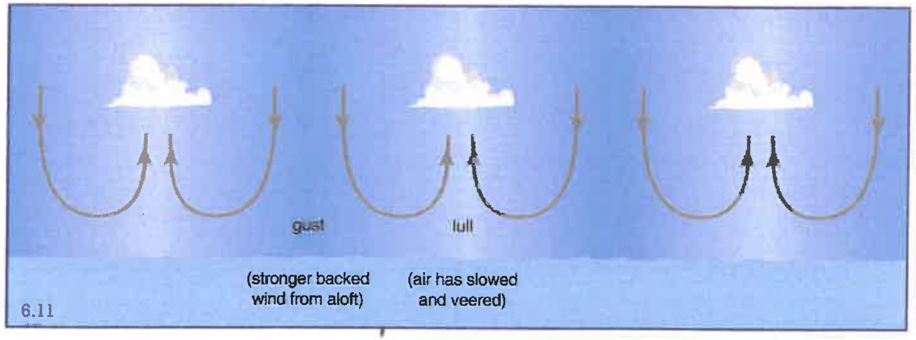
Over the open sea you must expect bands in the wind. Figure 4.1 applies without amendment, but the direction of drift of the bands is reversed (Figure 6.9). So if the wind is lighter than you think it should be , sail on starboard tack (or gybe) until you find the stronger wind, then tack on to port to stay in it as long as possible.

Influence of water temperature

The wind is always stronger and more backed over the warmer water. The changes in water temperature found near estuaries or at the meeting of different currents result in bends and bands in the wind in the same way as for land-sea boundaries (Figure 6.10).

Gusts and lulls

These are no different from what are experienced in the Northern Hemisphere except for a bias towards a back in a gust and a veer in a lull, especially close to the coast with an offshore wind. Figure 6.11 completes the picture for a typical trade wind cloud pattern.



6.11

7 The sea breeze – pure and simple

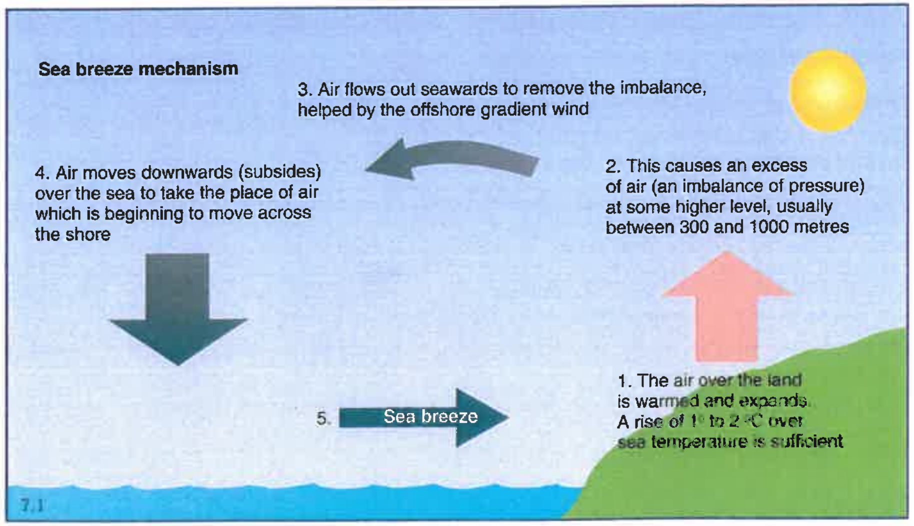
The term 'sea breeze' is often used very loosely to denote any wind blowing onshore. But if we are to recognise, understand, and use the changes in coastal winds which occur as the land warms, we need to be more precise and disciplined in our terminology. In what follows the term 'sea breeze' is restricted to mean the wind which blows onshore when the warming of the land by the sun generates a closed circulation, the onshore breeze near the surface being supplied by air moving offshore in the same general area but higher up. This 'sea breeze' has very distinctive characteristics, which are predictable and usable. Distinguishing between it and other onshore winds is essential to answering the question 'which side will pay?'.

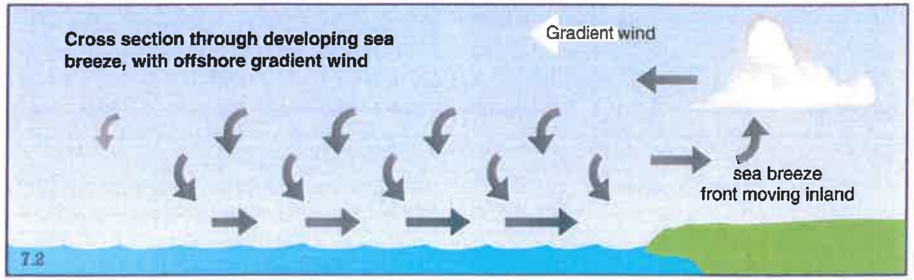
For the purposes of this chapter it is assumed that there is no gradient wind. While this may not be the case very often it provides by far the easiest route to understanding the development and behaviour of the sea breeze throughout the world. In Chapter 8 we will see how the gradient wind encourages or inhibits the development of a sea breeze.

How it starts

It is a sunny or bright day. The air over the land is warmed more than the air over the sea and the sea breeze mechanism begins to operate as follows (Figure7.1):

1. The air over the land is warmed and expands. A rise of 1 °C to 2 °C above the sea temperature is sufficient to start the sea breeze process. Hence the presence of a thin cover of cloud is unlikely to prevent a sea breeze.
2. This causes an excess of air (an imbalance of pressure) at some higher level, usually between 300 and 1000 metres above sea level.
3. Air flows out seawards to remove the imbalance
4. Air moves downwards (subsides) over the sea to replace the air, which is beginning to move onto the land.
5. This is the sea breeze





It is worth noting that the time of start of the sea breeze is 'sun time' rather than 'clock time'.

How far and how fast?

Once it has begun the sea breeze develops quite quickly, penetrating steadily inland near the surface and extending further and further offshore aloft. The further it extends seawards the more subsided air there is to feed the new breeze crossing the coast, and the nearer you are to the coast the greater the quantity of subsided air passing by (Figure 7.2), so the stronger the sea breeze. Typically you will find the new (sea) breeze extending out seawards to 50 or so kilometres by mid-afternoon with a speed ranging from a knot or two at its seaward extremity to some 20 knots near the shore. The final, maximum speed depends mainly on the stability of the air, because this determines the height of the return flow aloft. In the stable air found in an anticyclone, typically when it is hazy, what is known as a 'subsidence inversion' acts as a lid on the sea breeze. The return flow is confined below a ceiling which may be as low as 500 metres, and with such limited room the sea breeze may not get above 5 to 10 knots. If the coast is mountainous and the 'lid' is below the tops of the mountains the return flow will be blocked by the mountains, and the sea breeze and its return flow confined to the valleys.

The amount the land heats up is relatively unimportant to the development of the pure sea breeze, and this is one of the features which distinguish it from other thermal influences on the wind which are discussed in Chapter 9.

Tactics

On a typical Olympic course with a race starting after the sea breeze has set in, the landward side of the course will always pay, the wind always being stronger nearer the shore.

Change in direction

Initially the sea breeze behaves as if it is being sucked into the land, and its direction is at right angles to the coast. As the sea breeze circulation develops, more and more air arrives at the coast, and since the land surface is rougher than the sea it slows down and starts to slide sideways, helped by the Earth's rotation, which also determines which way it slides: towards the right in the Northern Hemisphere, towards the left in the Southern. Having started blowing directly onshore, the breeze ends up blowing more along the shore, at an angle of about 20 degrees to the shoreline, taking a shoreline direction averaged over about 10 kilometres. The veer (Northern Hemisphere) is fairly rapid in the first hour and is complete in 2 to 3 hours.

Tactics

Bank on a veer from the onset of the sea breeze, rapid at first then slowing down, until the wind angle is 20 degrees from the shoreline.

Summary and signs

On a straight coastline and in the absence of any pressure gradient the sea breeze development proceeds as follows:

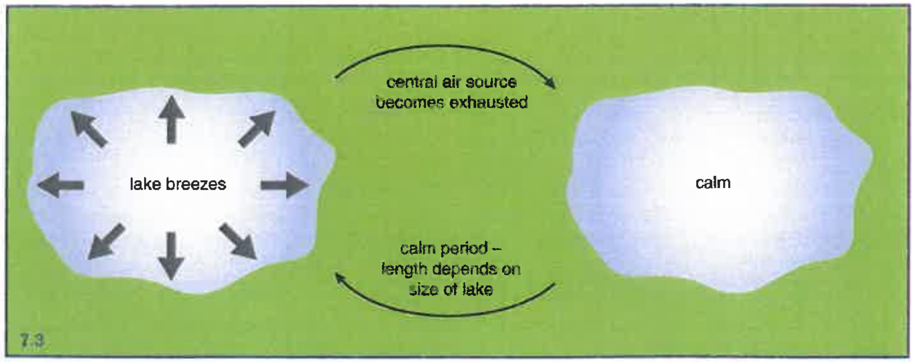
1. Calm morning, sky clear or cloud fairly thin
2. Temperature overland rises above sea surface temperature
3. Any low cloud just offshore begins to disperse – a sign of subsidence starting
4. Gentle drift of air starts onto the shore
5. Sea breeze increases steadily and extends both seawards and inland. Cumulus clouds often develop over land at forward edge of advancing sea breeze. But when the air is very dry the convection currents will be there but no cloud to reveal them.
6. Direction of sea breeze turns to the right (Northern Hemisphere) whatever direction the coast is facing. Typical change in first hour is 40 degrees. Strength continues to increase, with the maximum always near the shore.
7. Final direction – about 20 degrees back from the shoreline - is achieved about 3 hours from the start. Speed increases until about mid-afternoon. Maximum may be as high as 25 knots, but it depends on the stability of the air.
8. Sea breeze dies away at sunset, depending on how quickly land temperature falls. Decrease most rapid near the shore where it was strongest.

SEA BREEZE ON ANY COAST IN THE NORTHERN HEMISPHERE

The basic principles outlined above can readily be applied to any coastal situation, at least in relative terms. While it is unlikely that you will be able to predict precisely the wind speed and direction at any point on the racing area, you will with a little practice be able to judge for yourself where you are likely to find the strongest breeze, and the most veered or backed breeze. The two most important questions to ask are 'where is the air coming from to feed the sea breeze?' and 'is the source of air likely to be restricted?'.

'Sea breeze' on a lake

Take the simple example of a sea breeze on a lake. The driving mechanism is as in Figure 7.1, but depending on the size of the lake the source of air to feed the breeze is more or less limited. Figure 7.3 shows what happens. Only if the lake is 40 or 50 kilometres across is the breeze likely to be sustained for the



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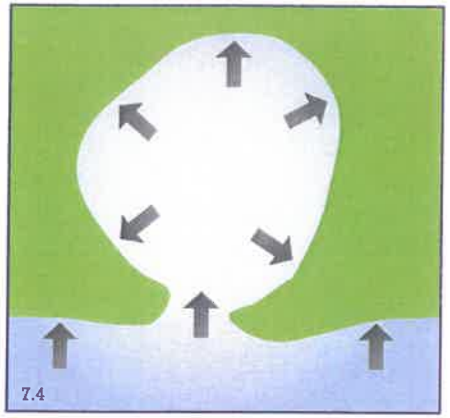
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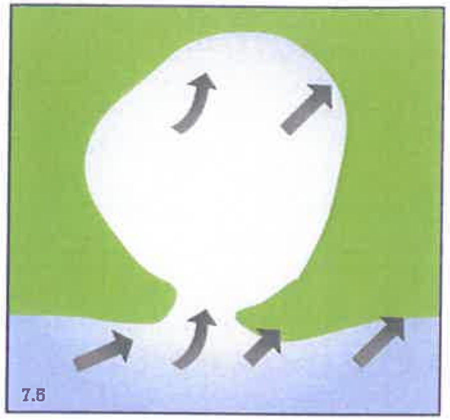

7.5

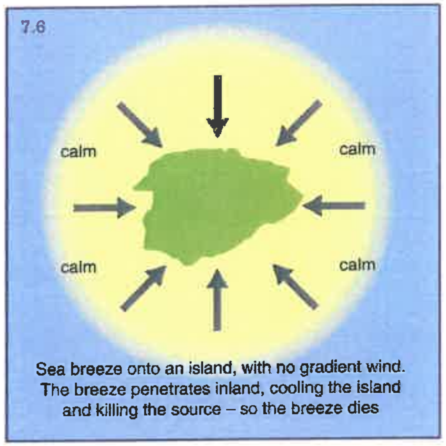
duration of an afternoon. With a smaller lake the supply of air to feed the breeze on to all shores becomes exhausted and the breeze dies away for a time before, having lost the cooling breeze, the land heats up again and the sea breeze cycle of waxing and waning is repeated. Typically for a lake 5 to 6 kilometres across the breeze cannot be sustained for longer than about 20 to 30 minutes before it dies for lack of air. For a smaller lake the period will be shorter, for a larger lake, longer. Breezes on steep sided lakes are discussed in Chapter 10.

'Sea breeze' in a bay

A logical next step is to consider the evolution of a sea breeze in a bay; the term 'bay' covering the whole range of coastal features from what is in effect a lake with a narrow opening at one end, to a wide open bay which is merely a gentle curve in a long stretch of coast. All-important is the availability of air to sustain the 'sea breeze' from outside the limitations of the bay itself. Figures 7.4 and 7.5 illustrate the evolution of a 'sea breeze' in and around a lake in the order of 10 kilometres across with a narrow opening to the sea outside. It is in fact modelled on Naragansett Bay on Rhode Island. Interesting wind patterns are found both in the bay itself, and also through and immediately outside the open end. The breeze starts blowing gently on to all the shores of the bay but after about an hour the supply of air from within the bay is exhausted except for air being drawn in through the opening. However the opening is too narrow to provide adequate support and the incipient breeze falters and dies except close to the opening. Then as in the case of a lake it starts again and the process of developing and dying is repeated. And what is going on inside the bay has a significant influence on the breeze through the opening, which pulsates as the demand for air from within the bay waxes and wanes. In response to these pulsations the developing sea breeze seaward of the entrance swings through 20 to 40 degrees as the demand for air changes. The nearer the coast the larger the swings. All this time the sea breeze is developing onto the coast to left and right of the bay. The extent to which the general coastal sea breeze eventually smoothes out the effects of the bay depends on the size and shape of the bay and the local topography.

Sea breeze onto an island

This is the opposite situation to a lake; there is plenty of air to feed the sea breeze, but hardly anywhere for it to go. If the island is flat and uniform a gentle breeze starts onto all shores and converges into the middle, with probably a cumulus cloud sitting there

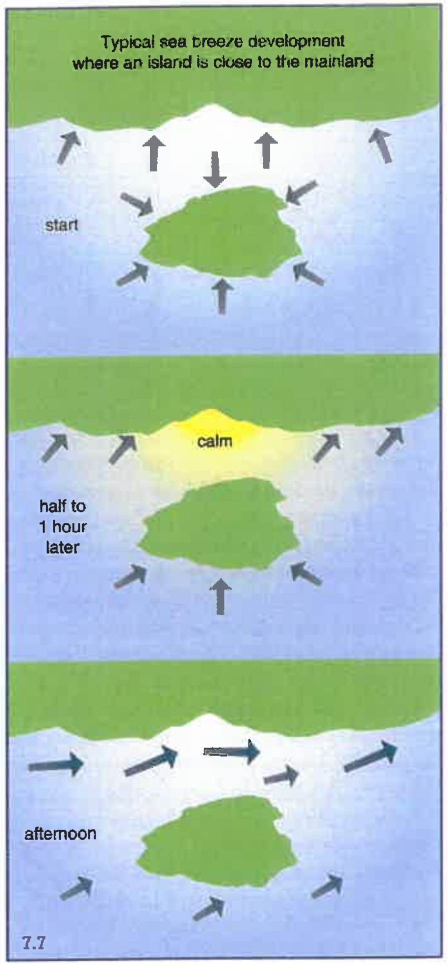


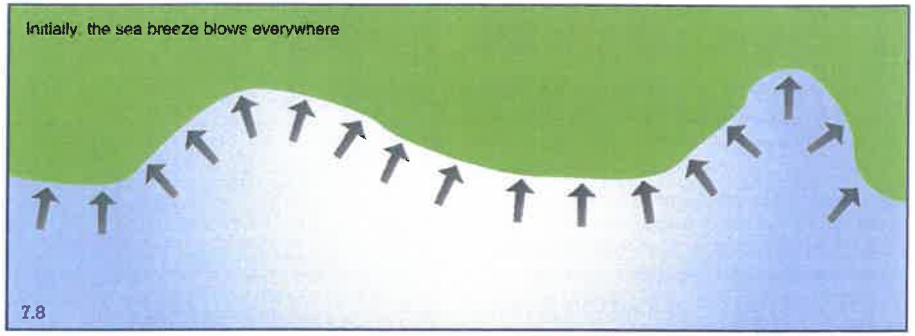
Sea breeze onto an island, with no gradient wind. The breeze penetrates inland, cooling the island and killing the source – so the breeze dies

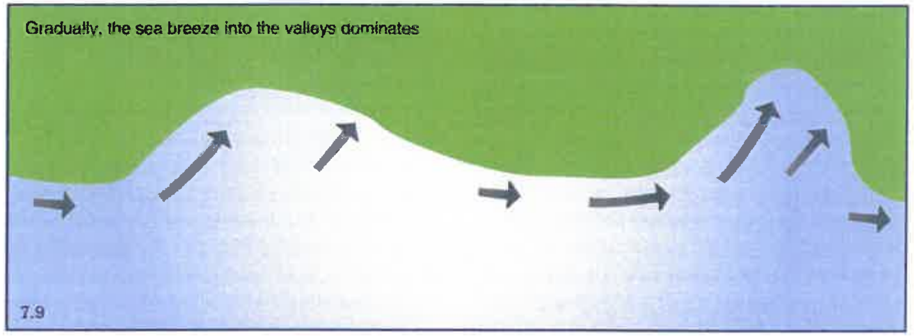
(Figure 7.6). Having cooled the island it dies, then starts again as the island heats up. Depending on the size of the island the breeze will pulsate. A period of some 20 to 30 minutes between calms is typical for an island 10 to 15 kilometres across. Put the island near a mainland shore and you have a situation similar to the Solent (Figure 7.7). Initially the sea breeze developing in the Solent pulsates between a few knots and calm due to the competing demands of the island and mainland shores. Then the developing breeze onto the mainland shore takes over and wipes out much of the influence of the island.

A mountainous coast with valleys

The sea breeze starts to blow onto all the land which is heated by the sun (Figure 7.8), that is, the valleys and slopes facing the sun. It is important to realise that the warming of the air by the ground which initiates the sea breeze is in this case far from uniform, with hot spots drawing the breeze more in one direction than another. And what is more the hot spots change as the earth spins on its axis. The slopes facing the sun early in the day move into shadow, cool off and 'hand over' to slopes facing more to the west. From mid-morning on we find that the various valleys are in competition as to which can draw in the most air. So do not expect a smooth and steady increase in strength of the sea breeze with a gradual veer until the final direction is achieved; rather a series of steps, even a snakes-and-ladders type progression in speed and direction during the day. Given an opportunity to reconnoitre an area for a few days prior to racing it should be possible to make some sense of the observed winds assuming that they are governed by the distribution and evolution of hot spots defined above.







Influence of anticyclonic inversion

When an anticyclone is present the depth of atmosphere in which the sea breeze can develop may be seriously restricted. An important feature of anticyclones is what is known as a 'subsidence inversion'. The air in an anticyclone subsides (moves downwards) and just as rising air cools due to expansion as it rises, so subsiding air warms through compression as it moves downwards. Typically this gives rise to a 'subsidence inversion' with a temperature maximum some hundreds of metres above the surface. This inversion, by acting as a lid on the sea breeze circulation, restricts its room for development and therefore its maximum speed.

An interesting example of what happens in the case of a valley surrounded by mountains with an anticyclone present was experienced in Korea at the time of the 1988 Olympics. The sea breeze was restricted to the valley behind Pusan because the lid imposed by the anticyclone was below the tops of the mountains. The sea breeze peaked at 6 knots.

Warm and cold water

The colder the water the more the subsidence of the air is encouraged which feeds the sea breeze. So given a choice the sea breeze prefers to start over the colder water. I have observed this off Newport, Rhode Island where on occasions the sea breeze starts from an area of much colder water some 20 kilometres southeast of Newport.

Chapter 23 gives examples of sea breeze development at some popular sailing venues. Travemunde Bay is wide open at one end; Christchurch Bay and Torbay are little more than gentle curves in the coast.

8 Sea breeze with gradient wind

Given the basic principles which determine the sea breeze – see Chapter 7 – we can think through how it is influenced by a gradient wind. We have seen that the two basic components of the sea breeze circulation are:

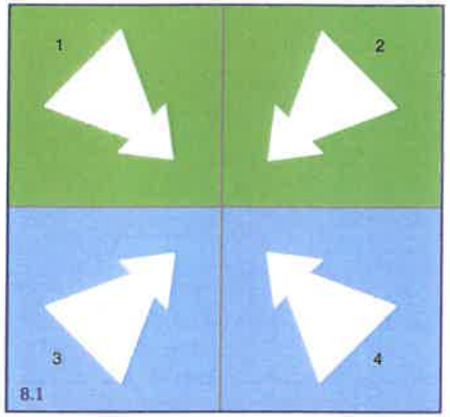
- A flow of air offshore at some height aloft
- The subsidence of air offshore

In the absence of a pressure gradient and therefore of a gradient wind there is no hindrance (or help) to either of these components and a sea breeze develops whenever the temperature of the land rises from a value below the temperature of the sea surface to a value above it. This temperature differential is clearly very important, but a warm, sunny day does not invariably guarantee a sea breeze. Over the past 30 years there have been several Cowes Weeks when the sea was cool (temperature 17 °C) and the air warm (temperature in the 20s), but no racing because no wind. Why? And what about Mediterranean coasts in summer? Some experience sea breezes and some do not. When working with the British Team at Kiel in preparation for the 1972 Olympics I well remember recording over 15 knots of sea breeze one day and less than 3 knots the next day, which was warmer. This was before I had discovered what controlled the sea breeze! I had expected an even better breeze on the warmer day and in the event there was barely enough wind to sail. The key factor every time and in every place was the pressure gradient wind.

Gradient wind direction

The sea breeze does not require a large rise in temperature to start it blowing – 1°C or 2 °C is sufficient – but it is critically dependent on whether or not the gradient wind is blowing offshore. An offshore wind supports the return flow of the sea breeze aloft and, so long as it is not too strong – 25 knots is the upper limit – the sea breeze has no problem tucking in near the ground beneath the opposite wind aloft. If the gradient wind, or a component of it, is blowing onshore it opposes the return flow which is essential to supply the surface sea breeze, and a true sea breeze does not develop. What happens with an onshore gradient wind is described in Chapter 9. It may seem to be a sea breeze, especially if it happens to be blowing from precisely the sea breeze direction, but it has markedly different characteristics, and you cannot win races if you confuse the sea breeze and the onshore surface wind resulting from an onshore gradient wind.

Given an offshore gradient wind, the way the sea breeze develops over the water is sensitive also to whether the gradient wind has a component from right to left or left to right along the coast. With a component from left to right there is some divergence in the streamlines of the surface wind over land and sea, which encourages subsidence (look back to Figure 3.8). Encouraging subsidence encourages the sea breeze which depends on subsidence over the water to feed it. By contrast, if the gradient wind has a component from right to left, the surface wind streamlines over land and sea converge and subsidence over the water is discouraged. These considerations – offshore versus onshore gradient wind, and diverging versus converging streamlines – provide the essence of a simple sea breeze model.



8.1

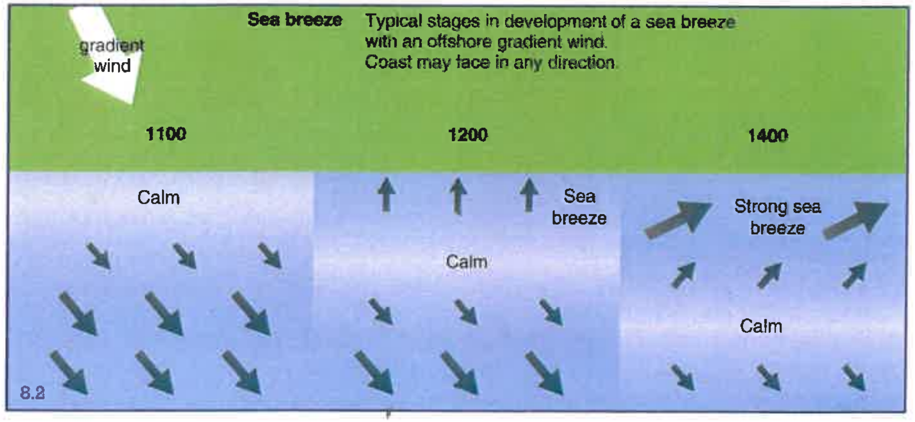
Sea breeze model

To predict both the likelihood and the character of the sea breeze on any coast anywhere in the Northern Hemisphere draw a line perpendicular to the coast. The four quadrants so created and numbered 1 to 4 (Figure 8.1) represent four ranges of gradient wind direction. For the rest of this chapter we will look in detail at what happens when the gradient wind is in Quadrants 1 and 2. A gradient wind in Quadrant 3 or Quadrant 4 opposes the development of a genuine sea breeze and is considered separately in Chapter 9.

Quadrant 1 This defines the range of gradient wind directions for the best sea breezes; between west and north on a south facing coast, between south and west on an east facing coast, and so on. Sea breezes may reach as much as 20 to 25 knots when the pressure gradient wind is in this quadrant. Many a sailor has been caught out assuming a dying offshore breeze mid-morning meant light winds for the rest of the day, when in fact it indicated ideal conditions for the best possible sea breeze.

The normal sequence of events starts with an early morning wind blowing offshore; then towards mid-morning, as the land warms, this breeze dies close to the shore and an onshore breeze begins, usually before mid-day. It is very shallow at first; smoke from tall chimneys still going straight upwards or even offshore. Over the next 2 to 3 hours the new sea breeze builds steadily, simultaneously pushing inland and extending seawards. It also veers, quickly at first, and then more slowly until it settles down blowing from a direction about 20 degrees back from the general line of the coast (Figure 8.2). The calm which precedes the new breeze, a zone of virtually no wind about 100 to 300 metres wide, moves out seawards ahead of it. The developing sea breeze is strongest inshore at every stage, and lightest at its seaward extremity.

If the initial surface wind direction is nearly



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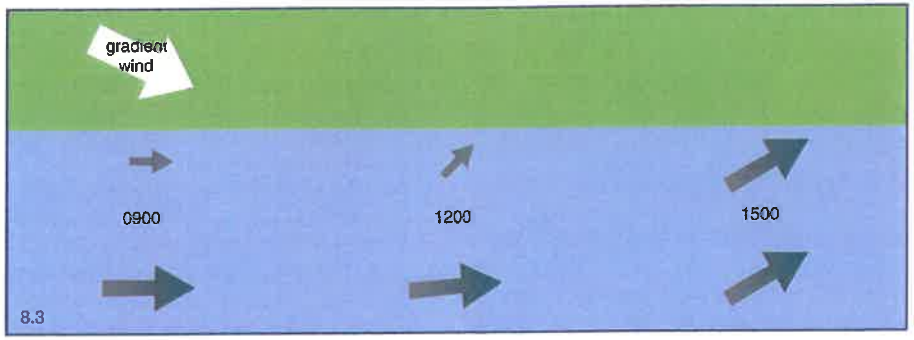
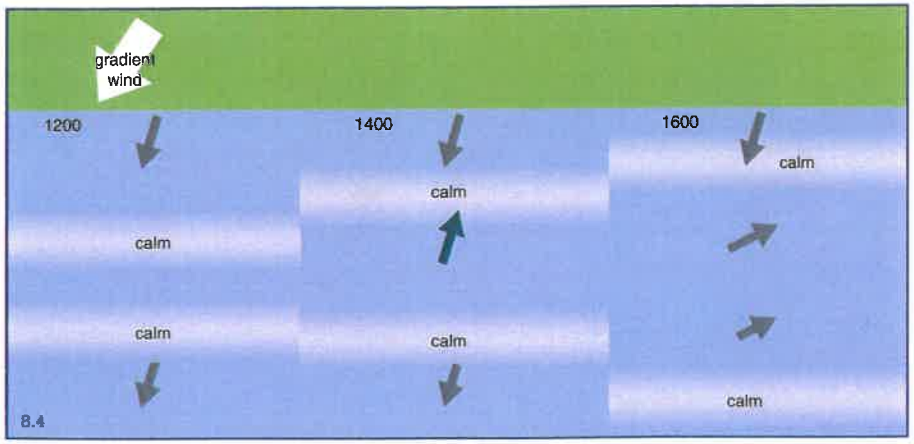
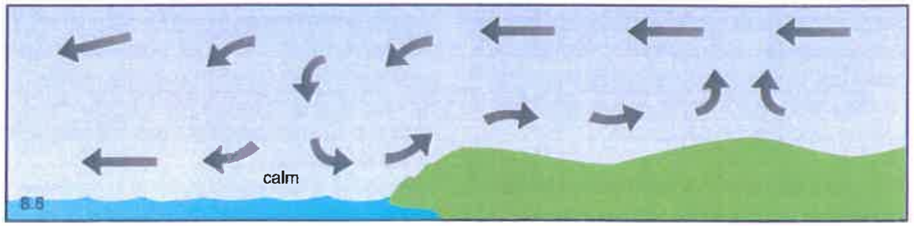


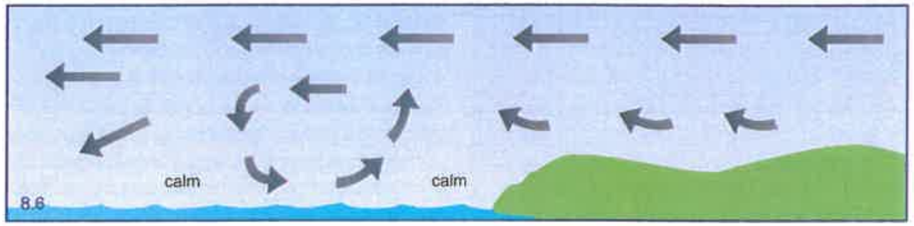
parallel to the coast (Figure 8.3) – and so long as there is a component of the gradient wind offshore – the onset of the sea breeze will merely back the wind near the shore, rather than kill it altogether. This backed wind extends seawards, increasing and veering to the final sea breeze direction, 20 degrees off the shoreline.

Quadrant 2 Here we are talking about gradient winds between north and east on a south facing coast, south and west on a north facing coast, and all directions in between. There is an offshore component of wind to help the sea breeze but particularly for winds nearly parallel to the coast, the problem is the convergence of wind streamlines near the shore (see Figure 3.6) which makes the air want to rise rather than subside. The sea breeze, which relies on air subsiding from aloft, is thus inhibited. In practice the sea breeze finds an interesting way to overcome the problem. It starts up seaward of the zone of convergence, several kilometres from the shore, and moves slowly in towards the shore as it develops (Figure 8.4). The nearer the gradient wind is to blowing along the shoreline the more pronounced is the convergence of winds near the shore so the further seawards the sea breeze may start. We then have the interesting phenomenon of boats beating in opposite directions towards the same point.

The zone where the two winds converge is usually a half to one kilometre wide, with no wind at all or light puffs from all directions.





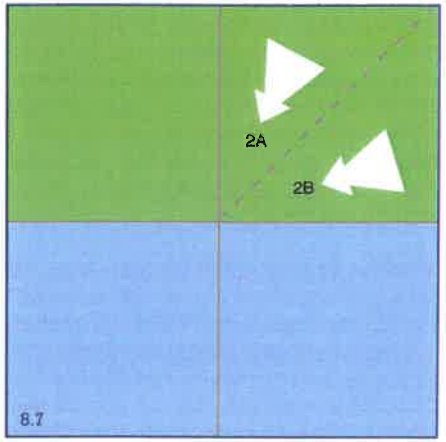


When the air is unstable the forward convergence zone is marked by towering cumulus clouds perhaps with showers, and its movement is erratic. Whatever happens inshore, the developing sea breeze extends out further offshore, separated from the initial offshore wind by a calm zone which precedes it. The developing sea breeze, sandwiched between the two calms, is fed by air subsiding from above.

Sea breeze calm zones

An important feature of the genuine sea breeze is the temporary zone of calm or very light winds which separates the initial offshore gradient wind from the newly developing sea breeze. Figures 8.5 and 8.6 help to visualise this in cross section. For gradient winds in Quadrant 1 (Figure 8.5) there is a single calm zone which starts close to the shore and moves out seawards at from 5 to 10 knots.

For gradient winds in Quadrant 2, when the sea breeze starts some distance seaward from the coast there are two calm zones (Figure 8.6). The most seaward calm moves out to sea as in the Quadrant 1 case, though rather more slowly. The inshore calm moves slowly towards the shore. If the gradient wind is more than 40 degrees from the shoreline (sector 2A, Figure 8.7) the sea breeze will cross the coast and move inland. If the gradient is within about 40 degrees from the shoreline (sector 2B Figure 8.7) the sea breeze is likely to stay just offshore, its position and alignment depending on coastal features such as bays and estuaries. For instance with an east-north-easterly gradient in the east Solent on the south coast of England the calm zone, typically marked by threatening-looking cumulus clouds, may stay offshore from Selsey Bill but move some distance north up the east Solent.



Strength, direction and signs

The sea breeze which develops with gradient winds in Quadrants 1 and 2 has all the same characteristics as the 'pure and simple' sea breeze described in Chapter 7.

Strength It increases steadily from a gentle start and is always strongest near the shore. It reaches a maximum by mid-afternoon and starts dying towards dusk. The final strength depends on the stability of the air. With a Quadrant 1 gradient wind and fresh cold air following a cold front it can reach 25 knots. If the depth of the sea breeze cell is limited by an anticyclonic temperature inversion, typically with a well defined layer of haze (see pages 12 and 33), 10 to 15 knots is a more likely maximum.

Direction It starts blowing directly onshore, veers fairly quickly in the first hour or so and achieves a final direction about 20 degrees back from the shoreline within about 3 hours. In low latitudes the swing is rather slower and the final angle to the shore some 10 to 20 degrees greater.

Signs The two most common signs associated with a developing sea breeze are in the low clouds. Patchy or thin low cloud moving offshore in a Quadrant 1 gradient wind starts to dissolve as soon as the air starts to subside just offshore to feed the newly developing sea breeze. At the same time or shortly afterwards, cumulus clouds start to develop onshore just ahead of the developing sea breeze as it pushes inland. If there is no cloud it does not mean there will not be a sea breeze. It may simply indicate that the air is dry.

Tactics

On a typical Olympic course with a race starting after the sea breeze has set in, or as it is just starting, the right hand (landward) side of the course will almost always pay, the wind always being stronger towards the shore. There are just two exceptions. Firstly in the case of a Quadrant 2 gradient wind with the sea breeze starting seaward of the coastal convergence, the sea breeze may not reach as far as the shore. But where there is a sea breeze its shoreward side will be the strongest.

Secondly if and when there is a low lid – 300 metres or so above ground – on the sea breeze due to an anticyclonic inversion – the evidence will be a low top on the haze layer – the sea breeze is likely to break up into cells. The breeze will still be strongest on the landward side of each cell but not necessarily near the shore.

Bank on a veer from the onset of the sea breeze, rapid at first then slowing down, until the wind angle is 20 degrees back from the shoreline.

Marginal cases

Gradient wind over 20 knots In my experience 25 knots of offshore wind is the upper limit for a sea breeze to develop. Between 20 and 25 knots the sea breeze may or may not develop, depending on whether everything else is just right. It is more likely when the gradient wind is in Quadrant1 and the coast is flat. Or it may keep trying to have a go, giving fairly violent swings in the wind but never quite making it. On an undulating coast you may find the sea breeze blowing onto one part side-by-side with the offshore wind. The two winds were experienced like this on an inshore race in the Admiral's Cup in Christchurch Bay in 1989.

Gradient wind nearly parallel to the coast This is discussed at the end of Chapter 9.

Examples

See Chapter 23 for examples of the development of sea breezes in the Strait of Dover, Thames Estuary, Seine Bay, Channel Islands, Solent, Plymouth Sound, Torbay, Christchurch Bay, West Coast of Scotland, Palma, Hyeres, Athens, and Medemblik.

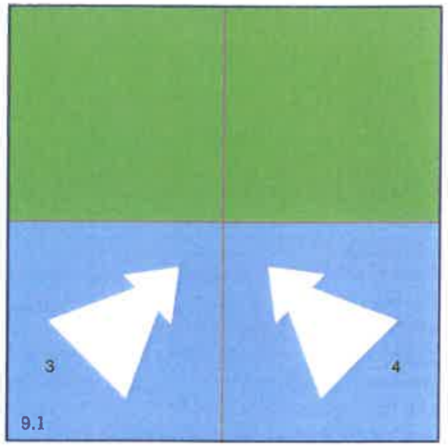
9 Afternoon winds – gradient wind onshore

Coastal winds when the gradient wind is onshore are not immune to the effects of rising temperature over the land, but they are modified in a very different way from the changes caused by sea breezes, and if you do not discriminate between the onshore wind, which is a result of an onshore gradient, and the genuine sea breeze of Chapters 7 and 8 you will be unlikely to win races.

It is useful to continue with the Quadrant model. Discussion of sea breezes focussed solely on Quadrants 1 and 2 where the gradient wind has an offshore component. We now turn to Quadrants 3 and 4 where the gradient wind has an onshore component (Figure 9.1). This opposes the genuine sea breeze which we can forget about – or almost forget! An onshore gradient wind has its own special features, for which it is useful to discriminate between winds in Quadrant 3 and Quadrant 4 for two important reasons. Firstly in Quadrant 3 for wind directions within 20 to 30 degrees of the lie of the coast we have diverging streamlines and lighter winds within a few kilometres of the shore, and in Quadrant 4 converging streamlines and a band of stronger winds within 2 to 5 kilometres of the shore.

Quadrant 3

A Quadrant 3 gradient wind is a south-westerly wind onto a south facing coast, a north-easterly on to a north facing coast and so on. A wind in this quadrant requires the pressure to be relatively low over the land compared to over the sea. Since heating of the land during the day causes pressure to fall, the low becomes lower; and since the pressure over the sea stays the same the



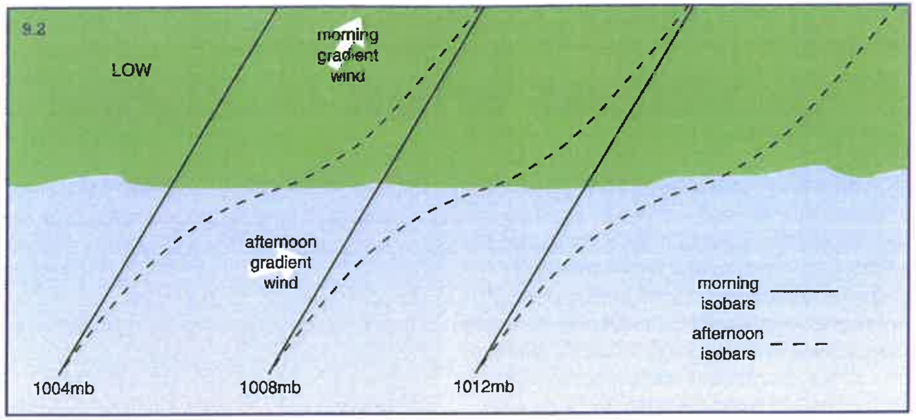
9.1

pressure gradient increases and the wind must therefore increase.

The fall in pressure over the land between mid-morning and mid-afternoon is typically in the order of 2 to 5 millibars; the greater the rise in temperature the greater the fall in pressure. Translated onto the weather map this puts a bend in the isobars towards lying parallel to the coast (Figure 9.2). In wind terms this means an extra component of gradient wind near the coast and parallel to it, or an extra component of surface wind from a direction about 15 degrees back from the shoreline. I will call it the **thermal component**.

Diurnal change in speed and direction

The change in the onshore wind as the land heats up depends on the relative strengths and directions of the gradient wind and the thermal component. In vector terms the thermal component gradient wind vector is



always parallel to the coastline and between 1 and 6 knots depending on the temperature rise over the land. If the morning gradient wind is also parallel to the coastline then expect the maximum increase in speed due to heating – about 6 knots – over the 1 to 2 km of water close to the coast. For a Quadrant 3 gradient wind the easiest way to judge the change in gradient wind due to the thermal component is to redraw the isobars on the weather map about 4 millibars closer to the coast (Figure 9.2) and infer or measure the new gradient wind. Later in the day, as the sun goes down and the land cools, the thermal component disappears and the wind returns to its former strength and direction, subject of course to no overriding changes due to the movement of weather systems.

It is important to note that the thermal enhancement is roughly of the same magnitude as the decrease in wind near the coast due to diverging streamlines (Figure 3.8). So the net effect is to remove the zone of slacker winds during the afternoon. Close to the coast a slight bend inshore is likely to persist.

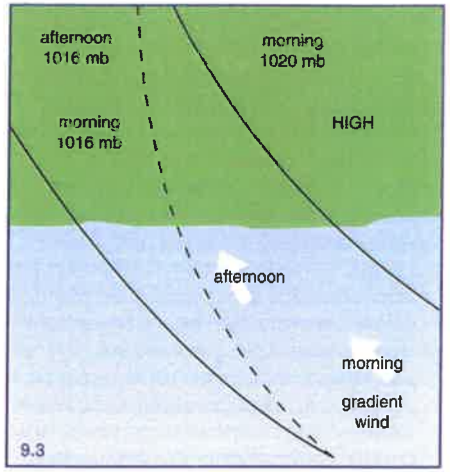
Differences from the true sea breeze

The main differences between the thermally-enhanced wind and the true sea breeze are:

- The morning wind does not go through the sequence of calm; light and directly onshore; veering and increasing.
- The full speed benefit of the thermal enhancement is achieved only when the morning wind is in about the same direction as the thermal. If the morning wind is directly onshore you can expect a small veer but little increase in speed.
- The change in direction is not as great, unless the morning wind is very weak and almost directly onshore. With stronger morning winds the afternoon wind direction will only be near that of the true sea breeze if the morning wind direction is near it to start with.
- The increase in speed is spread fairly uniformly over a coastal zone several kilometres wide. With the sea breeze the wind is clearly strongest near the shore, and decreases steadily as you sail out.

Quadrant 4

A gradient wind in Quadrant 4 is a south-easterly on a south facing coast, a north-westerly on a north facing coast, and so on. In this case the pressure is relatively high over the land (Figure 9.3), and the reduction in pressure over land due to afternoon heating causes a reduction in pressure gradient along the coast, and therefore in wind. The fall in pressure over land is the same as in the Quadrant 3 situation, typically



from 2 to 6 millibars; the greater the rise in temperature the greater the fall in pressure.

Change in speed and direction

As in the Quadrant 3 situation, the detail of the diurnal change in the onshore wind depends on the relative strengths and directions of the gradient wind and the thermal component. The easiest way to work out this change is to take the most recent weather map and reduce the pressure over the land by 4 millibars, while keeping it constant over the sea. In almost every case the gradient becomes much slacker, sometimes disappearing altogether. If it does disappear we move into the 'no gradient' situation of Chapter 7, and the decks are cleared for a pure sea breeze.

A good example is found on the Cote d'Azur in summer. The morning wind is typically between east and east-south-east with strength in the range 6 to 9 knots. By afternoon it has dropped to a mere 2 to 4 knots and the beaches are very hot. If the morning wind is only 4 or 5 knots it drops to calm by mid-afternoon and is followed by a moderate to fresh south-westerly sea breeze moving in from seaward, arriving sometimes as late as 1700 local time.

Tactics

There are no clear-cut guides to finding the strongest wind in Quadrant 3 and 4 situations on a sunny afternoon. In fact you must expect the wind to be relatively featureless within at least 5 km of the coast, without any notice-able structure, except large weak eddies when it has dropped below 4 to 5 knots. In this case you should make whatever way you can seawards, to pick up the new sea breeze at the first opportunity.

If it is cloudy and the wind fairly strong, heating of the land will be minimal and you should continue to look for the zones of stronger and lighter winds as shown in Figures 3.6 and 3.8.

As to wind direction, in a Quadrant 3 situation expect a gradual change towards 15 degrees back from the coast with a slight bend inshore close to the shore. Note that the change will be gradual – not rapid to start with as with the sea-breeze – and it may not stop swinging until mid-afternoon or until it has reached 15 degrees from the shoreline.

With a Quadrant 4 wind, the wind will veer as it dies. Do not expect a bend into the shore.

MARGINAL CASES

Gradient wind nearly parallel to the coast

In theory both the Quadrant 1/3 and 2/4 boundaries need to be studied; but in reality you only meet the Quadrant 1/3 situation – and you meet it quite often. The main questions to be answered are:

- Is there a component of offshore wind which will help to support a sea breeze?
- If there is an offshore component in the morning, will it last into the afternoon?

Small changes in the pressure pattern can easily tip the balance between an offshore and an onshore wind. The change in pressure due to heating of the land is a change you can predict for yourself, merely by noting whether or not it is sunny.

If the gradient wind is less than about 10 knots and the day is hot, a wind direction which is just inside Quadrant 1 in the morning may change to Quadrant 3. In this case the surface wind, initially alongshore and lighter near the shore, backs to what you would expect with the gradient parallel to the coast, that is, angled at 15 degrees on to the shore. The speed increases by 5 to 6 knots because of the increase in gradient, not because it is a sea breeze. There is no reason to expect the breeze to be either lighter or stronger near the shore than elsewhere.

If the gradient wind is blowing at more than about 15 knots, heating of the land is unlikely to shift it out of Quadrant 1, in which case you can expect Figure 8.3 to apply.

Tug of war

Occasionally, when the day starts with a morning Quadrant 1 gradient of only 3 or 4 knots you will find a genuine sea breeze developing on to the shore for about an hour or so, then as heating changes the gradient the sea breeze turns into a characterless alongshore wind angled at about 15 degrees to the coast and not increasing above about 12 knots. A bend in the coast of a few degrees may tip the balance for or against a genuine sea breeze, creating something of a tug of war between the two types of wind.

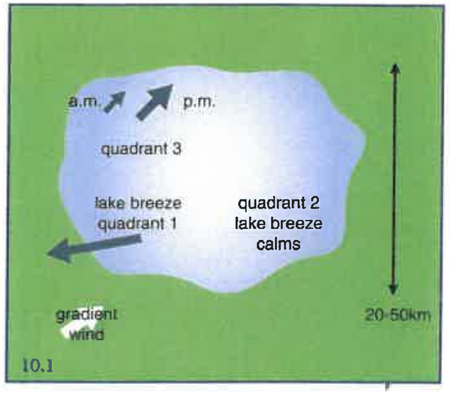
This situation occurs off Barcelona, where a change in shore alignment from 245° to 210° (Figure 3.9) makes marginal cases more frequent. It is impossible to predict in advance precisely how the light morning gradient will change during the day but the following simple on-the-water guidelines will help:

- Low cumulus or stratocumulus clouds continuing to move offshore and dissolve are evidence of an offshore gradient persisting; in which case expect a full sea breeze to develop, increasing to 20 knots inshore, rather less further out, and with the final direction about 20 degrees back from the shoreline.
- Low clouds which become stationary mid-morning, or a sea breeze which starts, then falters and fails to increase over a period of about half an hour, both indicate a change to an alongshore gradient due to heating of the land, in which case expect the afternoon wind to settle down to about 10 to 12 knots, angled about 15 degrees to the shoreline with a slight bend inshore close to the coast but no other significant features.

10 Lakes, mountains, valleys and peninsulas

The principles outlined in Chapters 7, 8 and 9 describing what happens when the land warms relative to the water can be applied to all coastal and inland waters of any size anywhere in the world. Some analysts, trying to catalogue their observations of coastal breezes have tried to distinguish different sorts of sea breeze, or have regarded each venue as unique, requiring individual classification. But in my experience there is just one sort of sea breeze which is generated in the same way the world over, and the one critical factor on which everything else depends is the direction and strength of the pressure gradient wind and its relation to the lie of the coast. With the whole compass range of possible wind directions there is scope for many sea breeze situations, but all of them are capable of being understood as outlined here.

On pages 30 – 32 we have looked at examples of the generation of sea breezes on lakes, bays and island shores in the absence of a gradient wind. We now turn to what happens in the presence of a gradient wind.



10.1

A lake

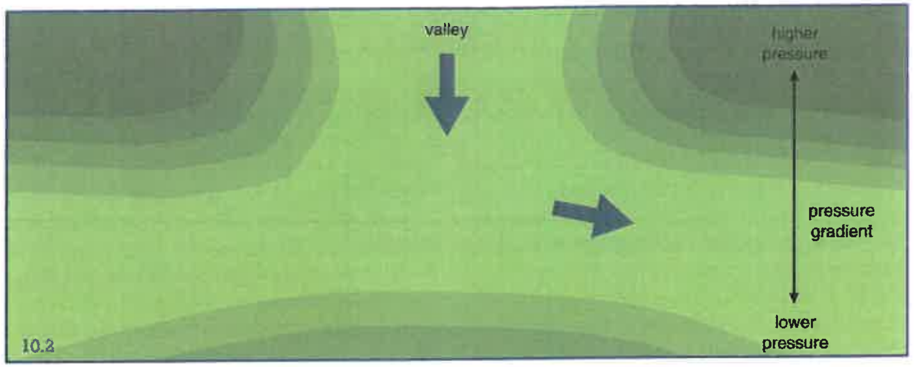
We saw on page 30 that many lakes are too small to support a lake breeze onto all shores. With a gradient wind blowing across the lake there is a greater chance of finding a reasonable lake breeze because it develops onto one shore only, the one for which the gradient wind is offshore, and it is preferentially supported from the area to the left of the breeze where the diverging streamlines encourage subsidence.

With a small lake, less than 10km across, the warming of the land around will result in a light lake breeze onto the upwind shore, but it will be fitful because there is not enough water area to support its full development. The larger the lake, the more likely you are to find significantly different winds on the various shores (Figure 10.1), depending on the angle of the gradient wind to the shore.

Mountains, valleys and steep-sided lakes

Four features characteristic of mountainous areas are:

- A bending of the pressure gradient wind to blow along the valleys, if it is aligned somewhere near their direction (Figure 10.2) to start with.
- The pressure gradient wind blowing across the tops of the mountains leaving only eddies in the valleys, similar to those of Figure 10.5.
- A drainage of cold air following the contours down hillsides and into valleys, particularly at night, known as a katabatic wind or, when it reaches the sea, a land breeze (see Chapter 11).
- Locally strong winds following a cold front



10.2

when cold air piles up against mountain barriers looking for the most convenient valley to exit to the sea. The Mediterranean provides some good examples. The Mistral is particularly well known and occurs following cold fronts reaching the Alps. The cold dense air behind the front is blocked by the mountains and rushes down the Rhone valley and out to sea.

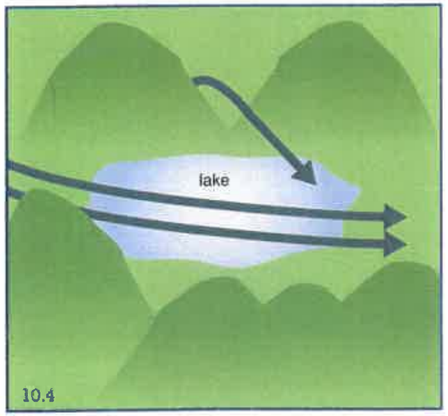
Breezes on steep-sided lakes

Steep-sided lakes exercise their own distinctive controls on winds blowing over them. The principles determining these controls are essentially those already discussed, so given the following examples you should be able to adapt the arguments to most if not all the situations you meet.

Little or no gradient wind, sunny or bright
The hillside facing the sun will become warmer than elsewhere and a lake breeze will develop onto this side, the warmed air rising and forming a closed circulation over the lake (Figure 10.3). The strongest wind will be close to the sunny shore. However, as the sun moves round so the warmed area will change and with it the position, direction and speed of the best wind.

Gradient wind blowing along line of valley
The surface wind will blow approximately in the same direction as the gradient, but its strength will depend on the stability of the air in the valley, and whether the valley is closed

10.3



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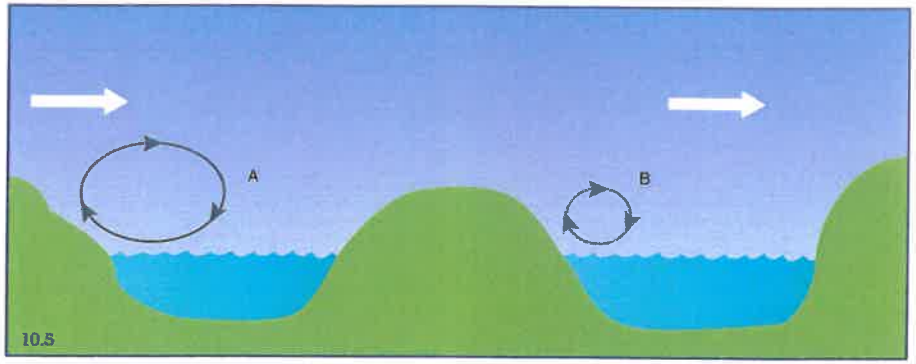
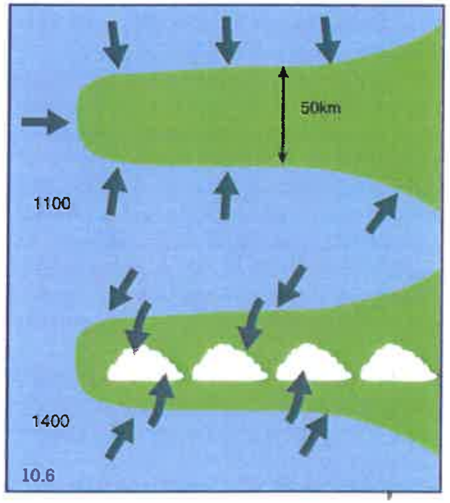


10.5

or open (Figure 10.4). If the valley provides a clear route through a mountain range the wind will funnel strongly along it, particularly when the air is stable and therefore reluctant to rise over the mountains.

Lake in a valley, gradient wind blowing across the valley
The air flow is likely to separate (Figure 10.5), and the steeper the slope the more readily it separates. The eddy forms on the side of the valley towards the gradient wind. The steeper the side the larger the eddy (A is larger than B in Figure 10.5).



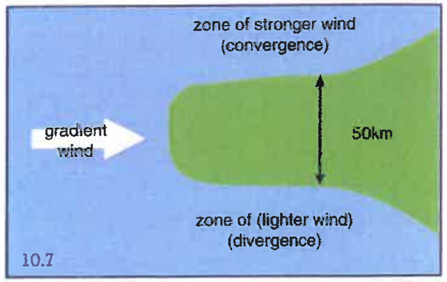
10.6

A peninsula

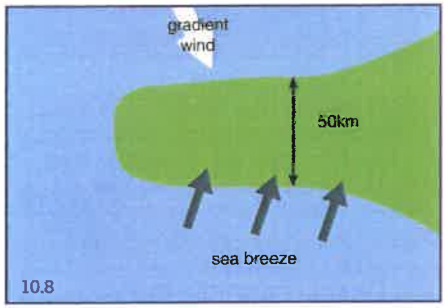
Let's look first at a relatively small peninsula, the size of Cornwall for instance. In the absence of a gradient wind, on a sunny day a sea breeze develops onto all shores (Figure 10.6), but the breezes onto the opposite major shores dominate and progress inland until they meet in the middle of the peninsula where a line of cumulus clouds may be seen. Once the two breezes meet they die. Then after 10 to 20 minutes or so the land warms again and the sea breeze process starts all over. To sustain sea breezes onto both shores throughout the afternoon without faltering the peninsula must be in the order of 100km wide.

In Figure 10.7 the direction of the gradient wind is along the line of the peninsula are the most significant surface feature is the bands of stronger and lighter winds respectively to be found just offshore. It is important to note that it will take only a small swing in wind direction to support a sea breeze onto one of the major shores. Starting from a wind parallel to the axis of the peninsula, a shift of only 5 degrees may tip the balance in favour of a sea breeze onto one or other shore, a shift probably outside the accuracy of the forecast. The onus is on you, the sailor on the spot, to interpret the wind trends observed on the water.

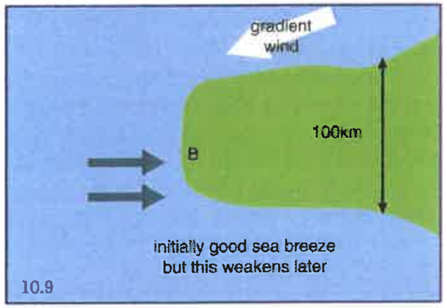
Figure 10.8 is a case for a good Quadrant 1 sea breeze onto the downwind shore, but a



10.7



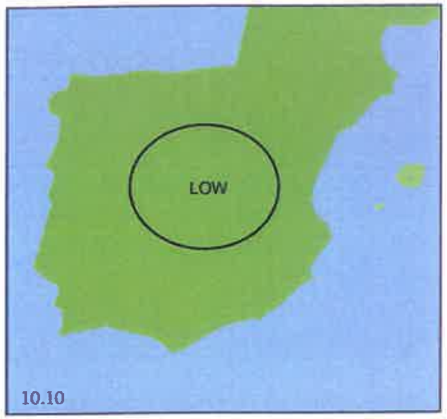
10.8



10.9

peninsula width of over 70 km is probably necessary for its full strength potential to be reached. Sea breezes generally penetrate inland at a speed of between 10 and 20 km per hour. From your knowledge of the width of the peninsula you can make a very rough estimate of how long it will be before it gets to the other shore and starts to die.

The fourth peninsula situation (Figure 10.9) is interesting. The breeze starts on to the end at B, a quadrant 1 situation, but as it veers and bends to the coastline it increases on the more southerly facing coast, and dies



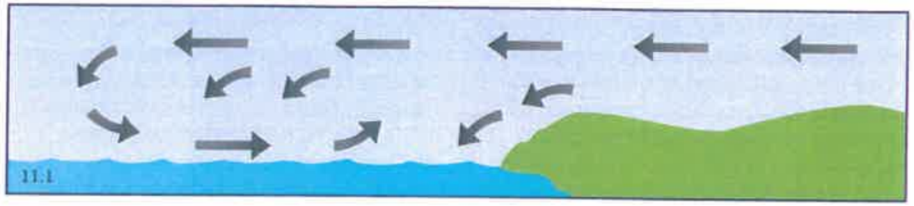
10.10

away at B with some bending of the wind around the corner.

Spain

Spain is a good example of a very large peninsula, and winds around Spain in the summer half year are a good example of a Quadrant 3 situation. For much of the summer the weather map shows a shallow low pressure area over the country (Figure 10.10), and each day the pressure falls some 3 to 5 millibars due to the heating of the land, recovering at night. The detailed shape of the isobars varies from day to day. It is often influenced by thunderstorms breaking out in late afternoon and continuing into the night, especially in late summer. On average the morning gradient wind is parallel to the coast and just in quadrant 3, light southerly on the Mediterranean coast, light northerly on the Atlantic coast, and so on. Every afternoon the thermal vector, also parallel to the coast, enhances the morning wind to give an afternoon onshore wind typically in the range Force 2 to 4 at an angle of about 15 to 20 degrees to the coast. It is blowing onshore but is not a sea breeze, and does not have the important characteristic of a sea breeze, which is to be strongest close to the coast.

11 As the sun goes down


11.1

In coastal waters the three main things to consider as the sun goes down are:

- The decay of the sea breeze
- The change in pressure gradient as the land cools
- The onset of a land breeze

The decay of the sea breeze

The sea breeze, which requires an offshore gradient wind in Quadrants 1 or 2 (Figure 8.1) dies fairly quickly as the sun stops heating the land. After a brief interval of calm the offshore gradient takes over again, an offshore wind reappearing near the shore – within 1 km or so – then extending steadily seawards (Figure 11.1). The stronger the gradient wind the quicker it returns.

If possible check whether there has been any change in gradient wind since you last saw a weather chart. Your best on-the-spot guide will be the movement of any low cloud that may be around. If the sky is clear the cooling of the land will mean a rapid decrease in wind over the land (see Figure 2.7), so do not stand in too close to the shore, at least not until a land breeze starts.

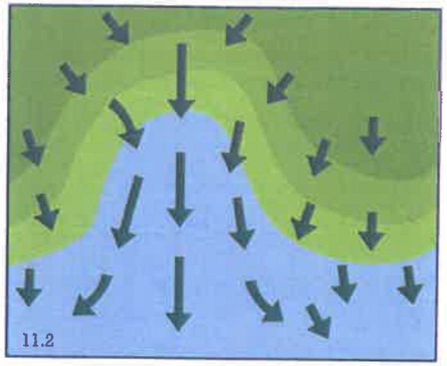
Change in gradient

If the gradient wind is in Quadrants 3 or 4 the cooling of the land will remove the afternoon thermal vector and the gradient will revert to what it was earlier in the day; that is, assuming, of course, that there has been no over-riding change to the lows and highs on the weather map. The Quadrant 3 wind will become relatively light again within about 5 km of the coast, and the Quadrant 4 wind will become that much stronger inshore.

The land breeze with little or no gradient wind

The best way to visualise a land breeze is as a 'drainage' wind, flowing down hillsides, into valleys, and out to sea rather like water would do (Figure 11.2).

On a clear night the land cools rapidly, and cools the air close to it, causing a temperature inversion. This cold air is relatively dense and so drains downwards following the contours of the land: the steeper the slope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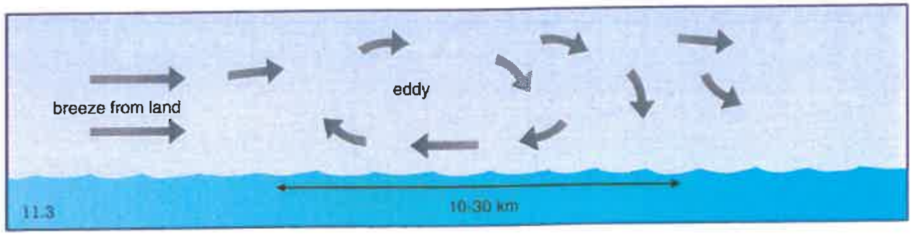


11.3

the stronger the breeze. On reaching the sea, which is almost invariably warmer than the land breeze, it spreads out fanwise and its momentum carries it 2 or 3 km out to sea before it has warmed up to the temperature of the sea surface, and stops moving. Salcombe harbour (Chapter 23) provides a good example of the relationship between the land breeze and the state of the tide.

On coasts with relatively little high ground the land breeze is inevitably weak. You have to stand in very close to benefit. Near mountainous country, on the other hand, land breezes may reach 30 knots or more and extend 50 or more kilometres out to sea (see also Chapter 13). After blowing for a few hours the breeze is turned to the right by the influence of the Earth's rotation.

An offshore gradient wind may be enhanced by a land breeze, particularly downwind from a valley; instead of the wind dying inshore as night falls, it keeps going.

When the gradient wind is onshore the development of the land breeze depends on the strength of the gradient, and whether there is coastal convergence or divergence (Figures 3.6 and 3.8). With a light wind and coastal divergence you can expect to find a shallow land breeze close to the shore

beneath the onshore wind, especially near a valley. With on onshore wind of Force 4 or more and coastal convergence, only a mountainous coast will produce a land breeze.

Offshore

Offshore you should look for the following as night falls:

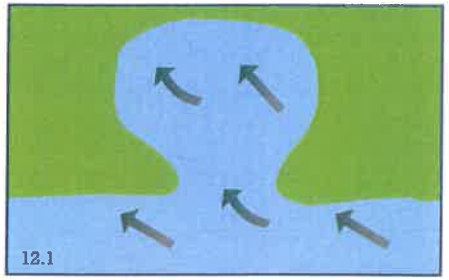
- Under a cover of low cloud a gradual increase in wind in the order of 1 to 6 knots is likely as the top of the cloud cools (see page 13). You will have to judge for yourself whether there is high cloud present to reduce the cooling of the low cloud top.
- If there are large cumulus or cumulonimbus clouds around there is an increased likelihood of showers or thunderstorms as the cloud tops cool. To avoid a storm try to leave it to port (see pages 57-58). This advice does not apply in the Doldrums where the storms move from east to west most of the time. And in any case you will probably be looking to the storm to provide some wind.
- If the breeze is offshore and you are within 200km or so of a coast, you may meet a temporary reversal in wind as dying remnants of the previous afternoon's sea breezes roll away from the coast on the offshore gradient wind (Figure 11.3). A typical sea breeze eddy moves out from the land at something like two-thirds of the component of wind speed perpendicular to the coast, so you can make a rough estimate of its arrival time. Assume that the sea breeze has reached 50km offshore by about 1700 hours.

12 Afternoon and evening winds – southern hemisphere

Let us now consider the features described in Chapters 7 to 11 with reference to the Southern Hemisphere. We saw in Chapter 6 that the arguments about unequal heating and cooling of land and water by day and night are virtually identical. The relevant diagrams are largely mirror images of those applying to the Northern Hemisphere as follows:

The pure sea breeze – no gradient wind

The sea breeze develops as a growing closed circulation as shown in Figure 7.1 with the onshore flow being supplied from air moving seawards at a higher level and subsiding over the colder water. Its characteristics and signs are as described in Chapter 7, except that instead of turning to the right it turns to the left, whichever direction the coast faces. The final direction is approximately 20

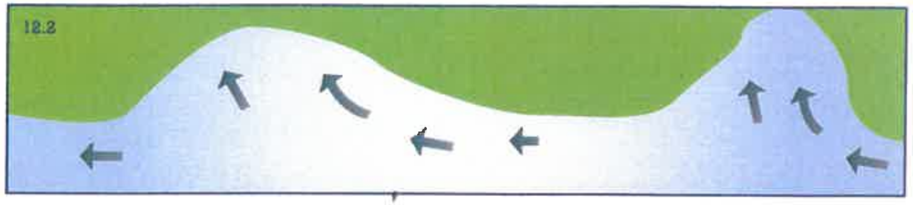

12.1

degrees off and to the right of the shoreline. All the Figures illustrating the initial stages of the breeze apply: 7.1, 7.2, 7.3, 7.4 and 7.6. But for the later stages, Figure 12.1 replaces 7.5, and 12.2 replaces 7.9.

Sea breeze with gradient wind blowing

As in the Northern Hemisphere, the sea breeze is critically dependent on the presence of an offshore component to the gradient wind. The Southern Hemisphere equivalents to 'Quadrant 1' are wind directions between east and south on a west-facing shore, between south and west on a north-facing shore, and so on (Figure12.3). These are the gradient wind directions for the best sea breezes which develop as illustrated in Figure 12.4 - or 12.5 if the initial surface wind direction is nearly parallel to the coast. In cross section Figure 8.5 still applies.

When the gradient wind direction is in Quadrant 2 (Figure 12.3) there is a tendency for the land and sea winds near the coast to converge, so the breeze starts seaward of the coast as shown in Figure 12.6 and we have two calm zones (for cross section see Figure 8.6), one moving seawards and the other toward the shore. The behaviour and speed of movement of the calm zones is as described on page 37.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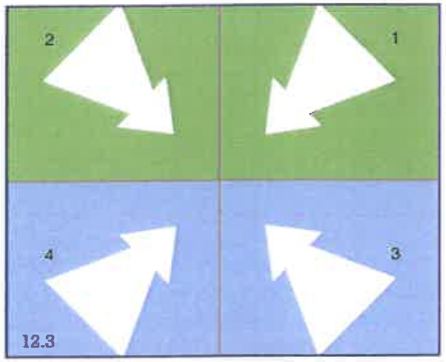


Afternoon winds – When the gradient wind is onshore

Although the wind is onshore it does not have the characteristics of the genuine sea breeze described above. Its behaviour is distinctly different in both speed and direction. Splitting the range of directions into Quadrants 3 and 4 (Figure 12.3) makes it easier to distinguish between the coastal divergence situation - land on your left facing the wind - and the coastal divergence situation - land on your right facing the wind.

Gradient wind in Quadrant 3

The pressure is relatively low over the land. Afternoon heating reduces it still further so that:

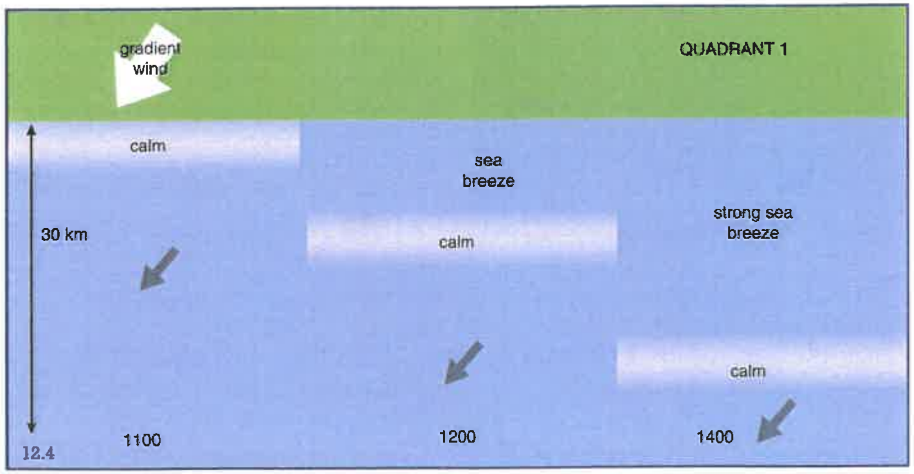
- The strength increases: ranging from an additional 5 or 6 knots if the initial wind is 15 degrees from the shoreline to virtually zero if the wind is directly onshore.
- The direction bends towards a line 15 degrees veered from the coast, by an amount depending on the strength of the gradient wind relative to the thermal enhancement. A light morning wind will be shifted more than a strong one.

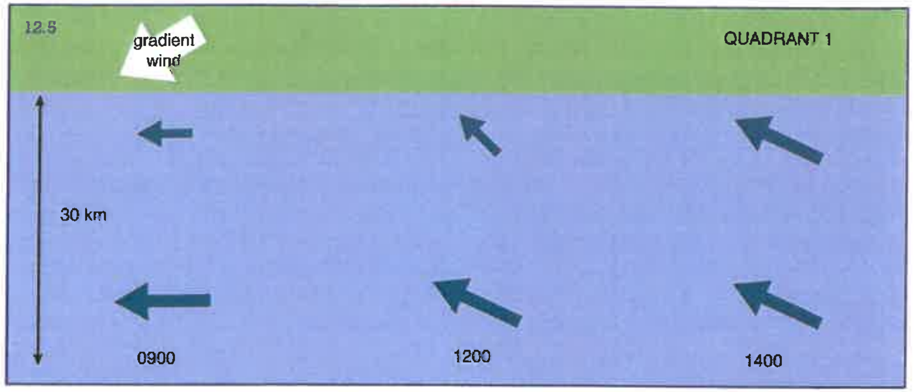
Gradient wind in Quadrant 4

The pressure is relatively high over the land and is reduced by afternoon heating so that:

- The strength decreases; the more it is aligned to the shore the greater the decrease.
- The direction veers; the lighter the morning wind the greater the veer
- If the gradient wind dies completely a late sea breeze follows.

The 'Fremantle Doctor' saga of the 1986 /7 America's Cup series provides a good example of the difference between a genuine sea breeze and an onshore gradient wind. Popular weather opinion was that the Fremantle Doctor was very reliable, guaranteed to blow on at least 90 per cent





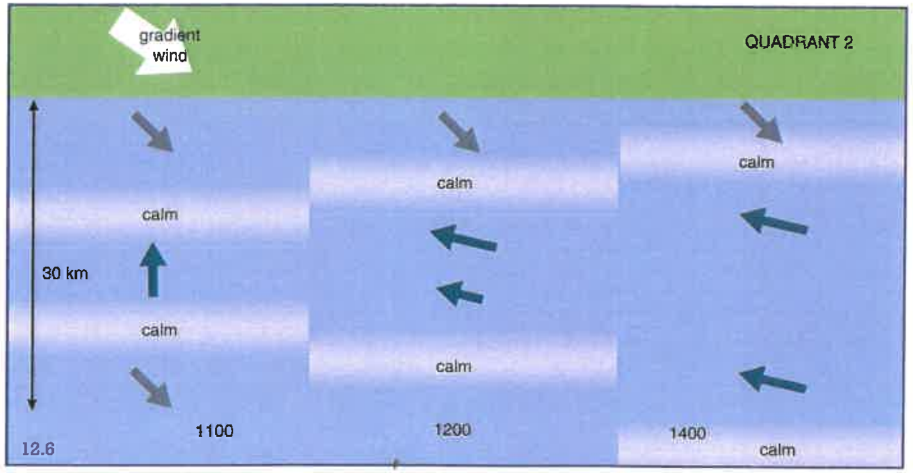
of afternoons, and invariably at Force 6. In the event Force 6 was experienced on less than half the occasions, while the more frequently experienced 12 to 15 knots was described as 'unusual'.

Based on the understanding of the relationship between the sea breeze and the gradient wind presented above, it proved possible on over 90% of days to predict correctly by 0800 local time whether the afternoon wind would be Force 4 or Force 6.

A south-easterly gradient wind (Quadrant 1) led to a Fremantle Doctor, the genuine sea breeze, blowing a Force 6 by mid-afternoon. An onshore gradient between south-south-west and south-west (Quadrant 3) signalled an increase by a mere 6 or 7 knots to Force 4. There were also predictable and subtle differences in the final direction for the same reason.

As the sun goes down

The dying of the sea breeze, the change in gradient as the land cools, and the onset of the land breeze all follow the pattern described in Chapter 11. The offshore wind reappears first near the shore (Quadrant 1 and 2 situations) then extends steadily



seawards replacing the sea breeze which continues for several hours over the water as a shrinking and weakening eddy, travelling along seawards driven by the offshore gradient. It may be as much as 12 hours before the last traces of the eddy have disappeared.

With a gradient wind in Quadrants 3 and 4 the gradient reverts to what it was earlier in the day – unless of course larger scale changes are in train. The nearshore wind maximum due to coastal convergence returns in the Quadrant 4 case, and the nearshore minimum if the wind direction is in Quadrant 3.

The land breeze

Being a drainage wind that flows down slopes and out to sea rather like water, the land breeze shows more or less the same characteristics in both Hemispheres. But if it has been blowing for a few hours it starts to turn to the left under the influence of the Earth's rotation.

13 Gravity waves, billows and surges

The term 'gravity wave' is used by meteorologists to embrace several wind phenomena, some of which are described in other chapters. A squall line sweeping out from a raining cloud (Chapter 14) is a gravity wave: cooled and relatively heavy air falls under gravity, then spreads outwards and hugs the ground. So is a land breeze, which I have also called a drainage wind (Chapter 11): cold, heavy air sliding down a hillside under gravity.

Another variety is experienced from time to time following some distance behind a cold front. It is sometimes called a cold surge. I met one during the 1-ton World Championships at Kiel in June 1991. A cold front had crossed from the north and the wind had veered to north-westerly Force 3 to 4 as forecast. An hour or so after the veer the wind suddenly increased to Force 6 for about 20 minutes, with vicious cold gusts and a further veer of some 40 to 50 degrees, accompanied by a rather ragged roll of low cloud. A thin layer of somewhat higher stratocumulus cloud at about 1500 metres showed no response whatsoever to what was going on below and continued to move slowly southwards. Taking all the evidence together this was a 'lump' of very cold air that had probably fallen off the Norwegian mountains. Being dense and heavy it was rushing southwards and hugging the ground behind the cold front which had probably triggered it in the first place. There was no sign of it at an altitude of 1500 metres.

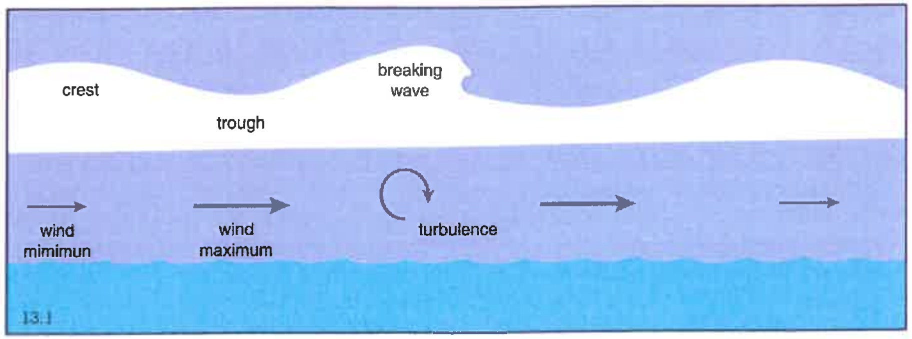
Maybe up to 20% of cold fronts are followed within a few hours by this sort of cold surge gravity wave, so be prepared. And they are not confined to seas downwind from mountains. Talking to Round-the-World crews after crossing the Southern Ocean it is clear that most of them have experienced a similar sort of cold surge following on the heels of a vigorous cold front, its origins presumably on the edge of Antarctica.

A 'cold surge' is also the name given by the Australian Bureau of Meteorology to a shallow layer of cold air following a cold front moving northwards up the east coast of Australia. The mountain range lying from south to north just inland from the east coast is part of the picture, but the most noticeable feature of these cold surges is best described as the relatively heavy and dense cold air looking for the easiest route northwards and finding it over the relatively smooth sea off the east coast. It just presses on northwards, regardless of the rougher land to the west which it leaves relatively windless; even Sydney Harbour is ignored.

Waves and billows

If you were to fly over a large area of low cloud covering the sea you might see a series of regular undulations – waves – in the cloud top, not unlike a long, low, sea swell. These are evidence of a wave motion in the air, not unlike what happens downwind from a cliff (figure 3.11). Meteorologists call them Kelvin-Helmholtz waves. Every few hundred metres you might see one of them breaking, just like a sea wave, with a ragged crest in the cloud and a suggestion of turbulence. This is a billow.

Beneath the cloud, and down near the sea surface (figure 13.1) you would find that the crests and troughs in the cloud top correspond to minima and maxima in the wind, with as much as 2 or 3 knots difference between them, similar to the



13.1

banding in the wind described on page 20. The breaking wave, or billow, would be producing turbulence right down to the sea surface with the speed and direction fluctuating wildly for 2 or 3 minutes – typically from 1 to 12 knots in an otherwise 6 to 8 knot wind. Such a billow coming out of nowhere can be quite unnerving until you realise what it is.

These waves only form in stable air. They were observed, for example, on the old America's Cup course at Newport, Rhode Island. But by far the most commonly experienced case of billows is in flight turbulence, often in clear air, but sometimes revealed by billow clouds which can be seen from the window of the aircraft or from the ground. The regular pattern of tufts in the cirrus or cirrostratus look just like a series of breaking sea waves.

14 The message of the clouds

Clouds tell of a wide variety of events in the atmosphere, some of them involving changes in the wind. Seen from a weather satellite orbiting thousands of kilometres above the earth the clouds act as dye in the air, mapping out the large-scale weather systems. The depressions are particularly noticeable with their attendant troughs and fronts, but there is also a wide variety of smaller scale arrangements of clouds, some of them giving clues to the existence of wind patterns which, if they can be identified, will prove useful to the racing helmsman.

Looked at from below, the clouds are just as meaningful but their message relates to events on a scale of a few hundred metres or so. Cumulus clouds, for instance, tell of pockets of rising air which are replaced by air moving downwards between the clouds. Occasionally there may be no wind except for the movement of air into a large cumulus cloud from all directions around it. In fact every cloud has a message of some sort, though not necessarily about the wind. The sailor needs to recognise features of the clouds which relate to the character of the wind – its gustiness for instance – or which foretell a change during the period of a race.

Many books on the weather concentrate attention on the major wind systems, the depressions and anticyclones, and a great deal is written about the clouds and changes in wind associated with their fronts, troughs and ridges. This information is of vital importance for anyone contemplating an ocean race; but a dinghy sailor about to compete for the next 3 or 4 hours on a small course is unlikely to be able to make much use of it, if only because it is almost impossible to predict precisely the time of arrival of a front and its associated windshift.

Of one thing I am certain, knowledge of the clouds can help win races. And the more you practise observing the clouds, their evolution and associated wind patterns, the more impressive will be your performance. I will not say much here about high clouds: those above 3,000 metres or so. Their message is normally about events far aloft or several hours ahead. I concentrate here on evidence of wind changes ranging from a couple of minutes to two to three hours ahead. But let us first consider a few simple observations which any layman might make and what we might deduce from them.

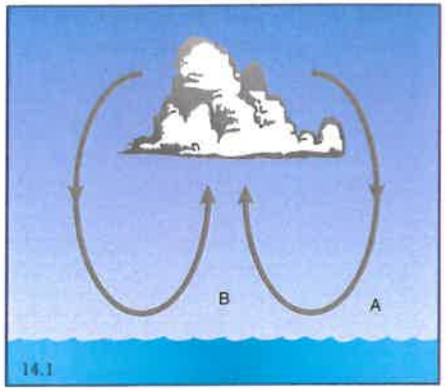
Black and white clouds

The colour of a cloud depends on how it is illuminated. If the sun is shining on it, it will appear white; if the sun is behind it, it will appear dark. If it is illuminated at a glancing angle when the sun is rising or setting, it will be beautifully coloured. This colour will change as the cloud moves or as the sun's elevation changes. The colour or change in colour of the cloud is of no consequence where the wind is concerned.

Similarly, an observer's impression of a layer of haze over the land or sea will change as the sun's altitude changes and must not be interpreted as presaging a change in wind. However the presence or absence of a layer of haze is very important to the sea breeze – see page 33.

Bent clouds

When cumulus clouds appear bent it means that their tops are moving at a different speed from their bases, i.e. there is a marked variation in wind speed with height.



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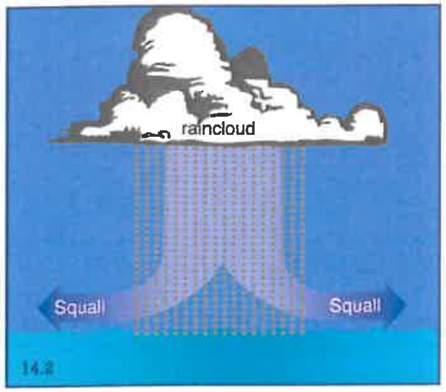


14.2

If the bent cumulus are low, say with a cloud base below about 500 metres, expect a greater than normal difference in direction between gusts and lulls.

Flat clouds

Flat clouds are characteristic of stable air. They often possess some shape or structure, usually due to warming or cooling of the top of the cloud, and this should not be interpreted in terms of any wind pattern at the surface. However, a large and distinctive feature appearing in a layer of low cloud is more than likely to indicate a change in wind. It may only be temporary, as in the case of a gravity wave (Chapter 13) or heralding the arrival of a new wind as a ridge of high pressure passes (refer to David Houghton's book *Weather at Sea*).

Lumpy clouds

The meteorologist's name for lumpy clouds is 'cumulus'. They are characteristic of unstable air, and are seen most frequently over land in the afternoon when the land surface temperature is maximum, when pockets of air heated at the ground rise until the cooling due to expansion brings their temperature down to the dew point of the air, when condensation occurs and cloud droplets form. The air will continue to rise until its temperature reduces to that of the surrounding air.

Look for a moment at a single cumulus cloud (figure 14.1). Air will rise from the heated ground into the cloud and be replaced by air moving downwards around the outside of the cloud, thus creating a very simple circulation pattern. If there is no gradient wind the cloud will be stationary, the only wind being the movement of air into the cloud, the size of the cloud giving an indication of the strength of this movement. For a small cloud, say 100 metres across and 300 metres vertical extent it will be less than a knot. For a towering cumulus cloud say 500 metres across and up to 5000 metres vertically it may be 15 knots or more.

In practice there is usually some pressure gradient wind, and the relatively gentle convergence of air into a small cumulus cloud is only a minor detail superimposed on the main wind. However, even with a small cumulus cloud there is likely to be a detectable difference between the wind at point A in Figure 14.1 where the wind is strongest and most veered, and point B where the wind is lightest and most backed.

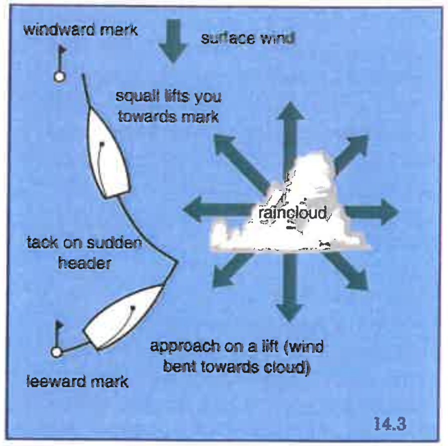
Raining clouds

So far we have looked at the air movements associated with relatively small cumulus clouds, those typically associated with fair or fine weather, when there is no sign of any rain falling. Rain however makes a fundamental difference to the wind characteristics of cumulus clouds. Why? Because as rain begins to fall out of the base of the cloud it evaporates into the air beneath and cools it, often by several degrees. This cooled air descends, and the more it is cooled the quicker it descends. So the relatively gentle movement of air into the cloud suddenly changes to become a squall of rain and air rushing out of it (Figure 14.2).

You do not have to go to sea to experience this cooling of air due to rain falling into it. Turning on a hot shower in a bathroom creates a sudden rush of cooled air down and out from the shower. At sea there is usually good visual evidence of the change. You can see the rain starting to fall, a greyish curtain appearing under the cloud and extending down to the water then outwards; sometimes there is a dramatic arch of black cloud advancing towards you. The squall is necessarily short-lived because there is only a limited amount of air below the cloud to be cooled by evaporation of the rain into it. Once the squall has passed the rain usually continues for a while, some 10 to 20 minutes for a typical shower cloud before it is exhausted. The wind coming out of the cloud then gradually dies away along with the rain.

Usually of course there is a pressure gradient wind blowing, but except in the case of a very light shower this is likely to be temporarily overridden by the squall, or augmented if they are both in the same direction.

On a typical showery day at sea there are likely to be cumulus clouds at every stage of development and decay, some not yet at the shower stage, others just about to start a shower, and others in the final stage of decay. So the wind you experience will depend on just where you are in relation to either a developing cumulus, a new shower with its squall, or an old and decaying one. It is important to watch each cloud carefully, and to be prepared to meet a dying eddy moving down the gradient wind which is the remains of a squall from a cloud which has largely disappeared.



14.3

Tactics

If you see a cumulus cloud raining or just about to rain, out to either side of the course, head for it. You will be lifted as you go across, and can then tack as the squall hits you and be lifted towards the mark (Figure 14.3). But don't head for a non-raining cloud – the effect is opposite and you will lose ground.

Thunderstorms

The larger shower clouds are named cumulonimbus and are often accompanied by thunder and lightning. They may tower to a great height- 8,000 metres is not uncommon and over 12,000 metres in the tropics. The top of a cumulonimbus often develops an anvil shape as stronger winds aloft carry it to one side. Aviators avoid these clouds because of the fierce up-draughts and downdraughts experienced - sometimes in excess of 60 knots.

A small thunderstorm (one or two claps) is likely to be very similar to a passing heavy shower, the pressure gradient wind being temporarily bent into the cloud, or replaced by the squall out of it. The majority of them move to the left of the surface wind (looking upwind). So if you want to avoid the storm set a course to leave it to port (Northern Hemisphere).

If you want more wind and need the shift from the storm use the tactics described above for a raining cloud.

The larger cumulonimbus may develop a complex and self-propagating structure with rain falling out of one part of the cloud while air is drawn into another part. They may last for at least an hour or two and should be avoided.

Safety A tall mast, just like a tree or any other free-standing object, will tend to be a focal point for a lightning discharge to earth, so it is important to ensure that the conducting route (metal) through to the water is continuous. If your mast is stepped in wood or glass fibre with no metal components extending below the waterline, a lightning strike is likely to result in a hole burnt through the hull. It is worth carrying a piece of anchor chain in thundery weather, long enough to hang from the shrouds into the water. Helmsman and crew are safe sitting well aft and not hanging onto the shrouds.

Lines or bands of cloud

The most commonly-recognised cloud bands are those associated with the large-scale fronts and troughs which feature on the weather map and are revealed in satellite pictures. The windshifts associated with them are major, often as much as 20 to 50 degrees, but it is rarely possible to pinpoint the time of arrival of a trough or front with sufficient accuracy to be of use when beating to windward on a typical championship course. A timing to within plus or minus an hour or two is normally the best that can be achieved. However, just occasionally a new wind is heralded by an advancing line or bank of low cloud to weather that is advancing from the direction from which you would expect any change according to the weather map. So, given a forecast of a change of wind direction without a precise timing, you should regard an advancing bank of low cloud as confirmation of the forecast and adopt a winning strategy.

More detailed knowledge of fronts, troughs and ridges and their associated cloud characteristics is essential of course in offshore racing and is considered in *Weather at Sea* in this series. But there is one high cloud sign worth mentioning here since it can prove useful.

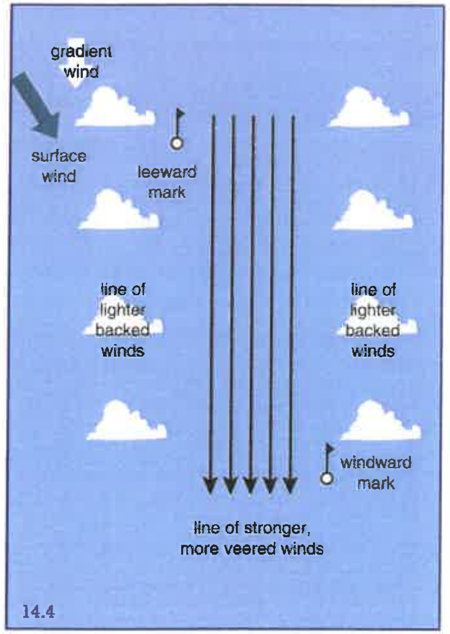
Occasionally a clear-cut cloud edge is seen stretching right across the sky, with blue sky or thin cirrus cloud on one side and thicker-looking high-level and perhaps medium-level cloud on the other side. If the cloud edge is stationary it is likely that there will be no change in the gradient wind for several hours. If the cloud edge is moving so as to bring increasing cloud towards you it is a sure sign of an increasing and backing gradient wind. The stronger the high-level winds revealed by the cloud band the greater the change to come.

Lines of low moving cloud – minor troughs

The most commonly experienced minor troughs are in cold unstable airstreams following the passage of a cold front and still in the circulation of a depression. A line of towering cumulus clouds advancing towards you heralds a windshift, often gusty, which may be anticipated to within a few minutes. If rain is falling out of the individual cloud turrets you can expect at least one dramatic change in direction with a squall coming out of the cloud before the wind settles to its new, more veered direction. You can either steer to avoid the squall or use it. The time interval between minor troughs of this nature varies greatly, but is typically from two to four hours.

Cloud streets

This is the name given to regularly-spaced lines of cumulus clouds which are often found over the open sea. They are associated with a pattern in the vertical movement of air which is like the horizontal roll illustrated in Figure 4.1. The best examples are found in the trade winds where the rolls extend for many hundreds of kilometres. The surface winds are relatively backed and lighter beneath the clouds, and veered and stronger in the intervening clear lanes (Figure 14.4).



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The differences are not great, only a few degrees, but are sufficiently regular to be worth using. When beating through the streets you will quickly discover the position of the cloud lines relative to the shifts and anticipate your tack accordingly. When reaching you will go through the gusts and lulls quite quickly, so constant sail trim will be needed. On the run, gybe on the shifts to keep the wind most abeam.

Lines of stationary low cloud

Stationary lines of low cloud are often found in the following situations:

- When standing waves have formed in the wind downwind from a cliff or hill (figure 3.11)
- When the wind is blowing nearly parallel to the coast and the land wind and sea wind are converging (Figure 3.6)
- When adjacent areas of warm and cold water cause local convergence of airstreams (Figure 4.3)
- When cumulus clouds generated over a particular hot spot on land are carried downwind forming a single cloud street.

The wind patterns experienced in the first three situations are discussed in the respective chapters. The stationary cloud street is likely to give a distinctive wind pattern over the water with a lighter, backed wind under the cloud street and a stronger, veered wind either side, so long as the water is not too cold. In stable conditions with the sea cold relative to the air, the cumulus street from the land may have little if any influence on the wind on the water.

Fog

Fog forms when warm moist air blows over relatively cold water, the water cooling the air to below its dewpoint (the temperature below which condensation occurs). Water temperature, be it sea or lake, varies from place to place due to the influence of rivers, currents, and wind. The incidence of fog is rarely uniform. In winter and spring the sea is normally coldest inshore so fog forms more frequently along the coast than out at sea. In summer and autumn the sea is normally coldest away from the shore so fog forms more frequently out at sea. Sometimes fog which has formed over land on a clear night drifts out over the sea, dispersing as it meets warmer water and clearing quite quickly up to masthead height.

In fog you should look for the following wind characteristics of stable air:

- Strong vertical shear – see pages 12 and 77
- Marked banding in the wind;
- An absence of gusts and lulls.

A cumulus 'street' lying along the wind direction (see page 59).

Stratocumulus in rolls.

Small cumulus, typical of fair or fine weather.

Cumulonimbus. A typical heavy shower cloud.

Altocumulus.

Cumulus marking a sea breeze front over the land.

Altocumulus castellanus – often precedes thundery weather.

Cloud increasing ahead of a trough.

15 Light airs

When the gradient wind drops below about 6 to 8 knots the surface wind on the water is likely to break up into either bands of wind or eddies. It is almost impossible to give clear guidelines as to the likely length and width of the bands or the size and shape of the eddies. The only certainty is that light winds are by nature fickle. However there are a few useful hints to be picked up from the preceding chapters, particularly the influences exerted by the sea surface temperature, nearby land, low clouds and water currents. The following list is not exhaustive or in any order of priority. Focus on whichever is the most relevant to your particular situation.

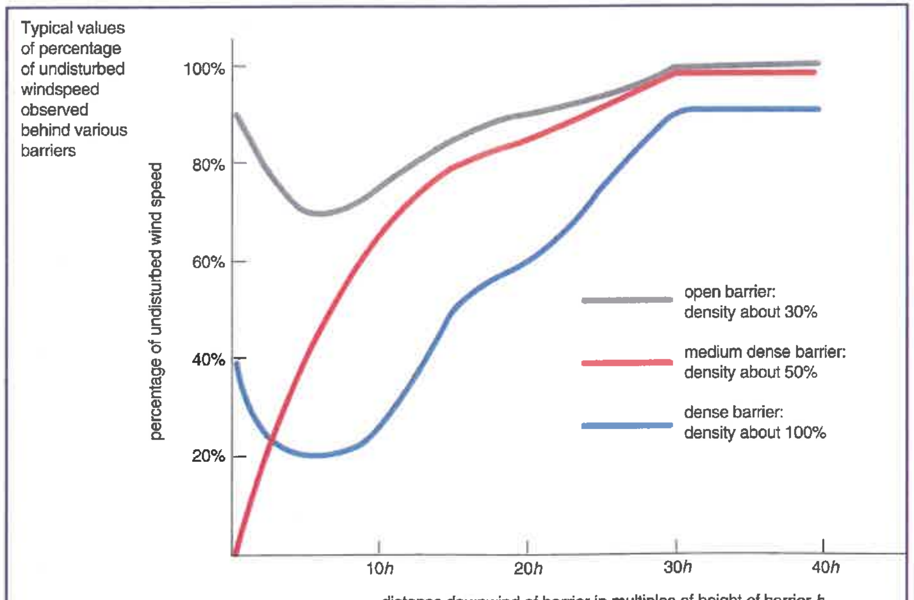
- Wind is most likely where the water is warmest, least likely where it is cold. What tidal influences are likely? Are you near a river mouth? See Chapter 4.
- Cooling of the land on a clear night will kill a light wind close to the coast, so stand off. See Chapter 2.
- On the open sea, well away from the coast, a wind band is likely to drift down the component of the gradient wind across it. It may not be more than half a kilometre wide, but if you are lucky enough to find one try to stay in it as long as possible by sailing on starboard tack in the Northern Hemisphere, port in the Southern. See Chapters 4 and 6.
- Cumulus-type clouds with bases below 1000 metres or so will be drawing air in from the surface; worth looking for if there is little else – see Chapter 14.
- At night there is likely to be more wind under a layer of low cloud – stratus or stratocumulus – than where the sky is clear. See Chapter 2.
- An area of smooth-looking water surrounded by a rippled sea may indicate absence of wind, but beware, smooth water is also a sign of upwelling – see Chapter 18.

16 Obstacles in the wind

A championship course will normally be sited well away from any obstacles which might interfere with the wind. Regattas on inland waters, however, can rarely be held in such ideal conditions, and river sailors in particular have to live with obstacles to the wind. So it is worth reviewing the various research projects which have been undertaken from time to time to measure the effects of different types of barrier on the wind. This has a spin-off for the sailor on sea courses who may well be faced with a 'barrier' of boats ahead, larger boats in some cases, when starting 10 minutes behind another class.

There are many types and densities of barrier: buildings, trees, forests, walls, fences, boats and poles. Some are short, some tall, but their influence on the wind is a function primarily of the height and average density of the barrier. Density might be loosely defined as the amount of daylight that a barrier lets through. Thus a brick wall has a density of 100%, a well-spaced row of trees a density of about 30% etc.

As a general rule, whatever the density of the barrier, you need to go approximately 30 times the height of the



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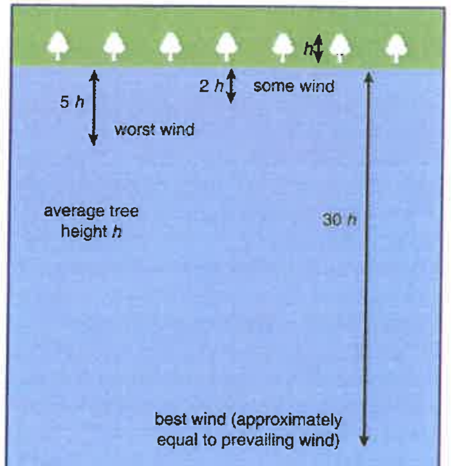

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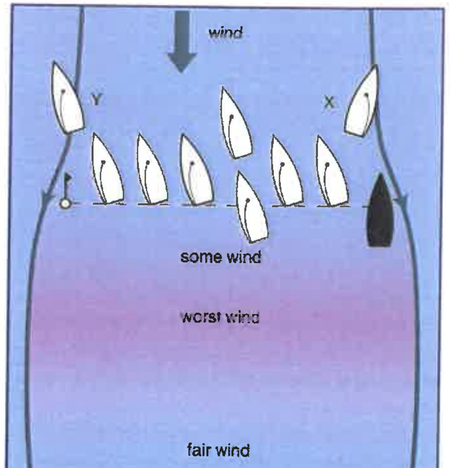

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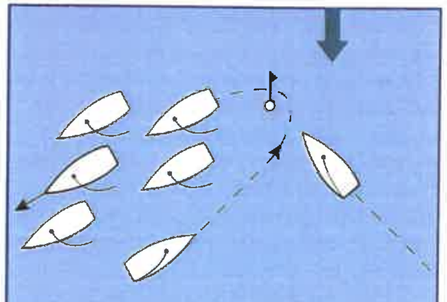
barrier downwind before you are clear of its influence. For river sailors this is virtually impossible, but all is not lost for over the last few decades a few simple (though not always obvious) guidelines have been developed which give a good indication as to where the best wind is likely to be found.

Figure 16.1 is taken from a study of winds downwind of barriers conducted by R.W. Gloyne of the UK's Meteorological Office some years ago. It shows in particular that:

- For all but the most solid barriers there is a zone of lowest wind speed about 5 times the height of the barrier downwind from it. Figure 16.2 shows where the 'worst wind' zone would be downwind from a line of trees.
- A medium-to-dense barrier is a much more effective obstacle to the wind than a dense one such as a brick wall or a thick hedge.
- For most barriers other than the medium-dense variety the wind recovers to 75 per cent of its original average speed at a distance of roughly 10 times the height of the barrier downwind.



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A massed start of 100 or so boats could be described as a medium-dense barrier and is likely to disturb the wind for a distance of 30 to 40 times its height downwind, i.e. up to 300 metres or so away. In Figure 16.3 note that the fleet at the start not only interferes with the wind but causes it to bend around the edges. Thus boat X (on port) and Y (on starboard) both experience a lift.

Figure 16.4 points up the dangers of approaching the windward mark on port tack if you are fairly well down the fleet. The boats already on the reach will form a medium-dense barrier to the wind in which it will be almost impossible to sail.

17 Water currents

Very rarely is water absolutely still. It is normally moving in one direction or another for some reason, and any movement is important to the racing sailor. Only if the movement is uniform over the racing area and constant throughout the period of the race can it be discounted, since it does not benefit one helmsman over another. If the current changes across the course or during the race it may be used to advantage.

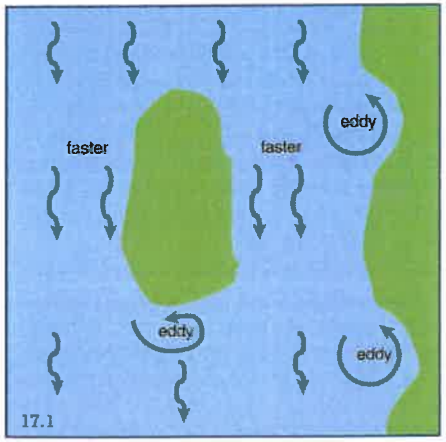
For any particular place the pattern of ocean currents may be gleaned from the Admiralty Pilot for the area, and the tidal streams can be worked out from the appropriate tidal atlas or nautical almanac. We want to consider here the variations from the data given in the tidal atlas or nautical almanac and show how to anticipate and recognise them. Variations can occur for four main reasons:

- Interaction with the coast or islands
- Variations in depth
- The wind
- Variations in temperature and salinity

Interaction with the coast or islands

You have only to stand on a river bank and watch the water flowing by to realise how easily eddies form in any bay or inlet, downstream from an obstruction or at the edge of a particularly fast part of the flow. Some of these eddies remain in the same place for long periods, others break away and are carried downstream by the main flow.

Spotting eddies at sea is often a matter of common sense coupled with observation. If a current is flowing past an obstacle, a bay or an inlet it is very likely that an eddy will form. The details of its shape and size, and whether or not it will break away from time to time, depend on the shape of the coastline and the depth of the water (Figure 17.1).



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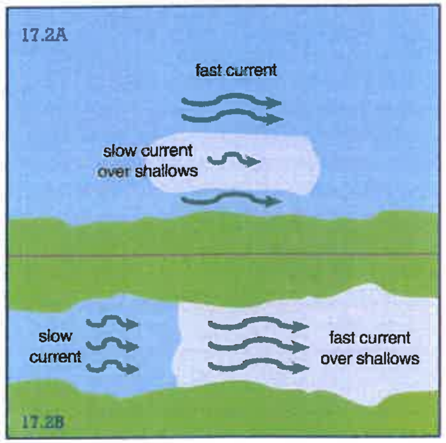


Variations in depth

Friction causes a current to slow down as it passes over shallows or close to the shore (Figure 17.2A). But if the shallows extend right across a channel the current speeds up because the water has no alternative route (Figure 17.2B).

The wind

We noted in Chapter 2 the influence of drag on the wind, slowing it down and causing it to back – some 15 degrees in the case of a smooth sea surface. The drag of the wind on the sea causes it to move as well, a movement which is most marked when the surface water is relatively warm or fresh, or both. The surface water is then stable. It does not mix with the deeper water and is driven downwind independently of it. A wind of 10 knots blowing over a stable surface layer of relatively warm water about one metre deep will accelerate it to a speed of about one knot within about 10 hours. The direction of movement of this wind-driven current is initially directly downwind, but the effect of the earth's rotation is a swing to the right – looking upwind – in the Northern Hemisphere (to the left in the Southern Hemisphere). The maximum swing is 80 degrees over a period of 24 hours in mid-latitudes, but near the coast the swing is constrained by the shore. In low latitudes the rate of swing is much slower.

Another wind effect is found in enclosed waters. A strong wind blowing for a day or more will pile the water up at the downwind end of the enclosure. The water movement is barely noticeable during the blow, but if the wind suddenly drops a significant current is experienced as the water returns to its original level (Figure 17.3). The time it takes for the water to return depends on the subsequent wind and the size of the area of water. At Kiel after a period of strong south-westerly winds the return to normal takes about 24 hours.

If the water is strongly stratified the return when the wind drops may take place through

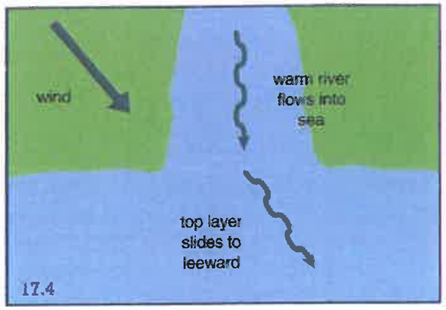
17.3

a bottom current rather than a surface one. On Lake Ontario for instance cold bottom water may suddenly appear as a strong wind dies away. A sudden drop in the temperature of the surface water will lead to a dramatic drop in windspeed.

Rivers

Major variations in surface currents must be expected near the mouths of rivers, and knowledge of the respective temperatures of the river water and the sea water are crucial to understanding what is happening on any particular occasion. The temperature of the sea water will vary with the tidal ebb and flood, and whether the river water is warmer or colder than the sea depends on the time of year. A thermometer is an essential element of kit. The river water, being fresh, will tend to stay on top of the sea water, particularly if it is warmer than the sea. A top layer of fresh and perhaps warm water will behave as a slippery layer and be driven by the wind independently of the water below (Figure 17.4). The 'slippery sea' experienced at the 1968 sailing Olympics at Acapulco originated at a river outflow some 80 kilometres down the coast. A shallow layer of warm (30 °C) fresh water overlying a colder (22 °C) opposing deep ocean current, was driven by the night breeze to lie across the racing areas off Acapulco harbour. To win a race it was necessary to pinpoint the positions of the opposing currents.

If the river water is much colder than the sea temperature, as in winter and early spring around the coasts of Europe and western North America, it will sink rapidly



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and will not influence local currents except very close to the river mouth.

Near coasts in general, particularly estuaries, it is not unusual to find significantly different currents in adjacent areas of relatively warm and cold water, the boundary being marked by a colour change and sometimes a band of pollution.

Do not forget the influence of the change in water temperature on the wind described on page 21.

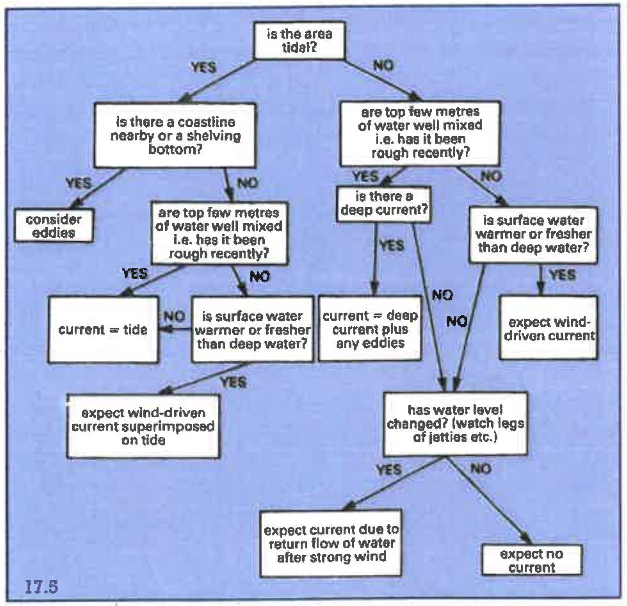
Observing the current

To measure the surface current you need firstly a fixed point and secondly an object which floats in the water, is easy to see and is not moved significantly by the wind.

Any moored buoy or lobster pot will do for the fixed point. The best and simplest float is a pole, one metre or so long, weighted with lead or rock at one end so that it floats vertically with a few centimetres visible above the water. Paint this top bit in a bright colour. A float like this will show the average current through the depth of water in which your boat sails. Drop the float alongside the fixed point and note the direction and distance it moves over a period of a minute or two. If you haven't a pole handy something like an apple core, which floats mainly below the water surface, will give a reasonably good idea of the current on most occasions. But be cautious how you use the information on a sunny afternoon with a smooth sea, because the water in the top few centimetres is likely to be 2 °C or 3 °C warmer than below, and the top few centimetres may be sliding downwind while the water only 6 or 7 centimetres further down is stationary.

Whenever you make observations of the current it is worth recording the temperature of the surface water as routine. Almost any thermometer is suitable, though some are easier to use than others. A swim will often reveal temperature variations of 1 °C or 2 °C: the body is sensitive to these sorts of differences. And you can swim with the thermometer in your hand or between your toes!

To predict the current during a race ask yourself the questions in Figure 17.5.



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18 Waves

It is customary to classify waves according to two types: wind waves which are produced by the wind blowing locally at the time, and swell waves which are generated by the wind somewhere else. The 'somewhere else' may be thousands of miles away. In both cases the height and distance apart of the waves depends upon:

- The strength of the wind producing them
- The length of time it has been blowing
- The fetch, which is the distance the wind has been blowing over the water
- The depth of the water
- In the case of swell waves, the distance the waves have travelled

Wind waves

Locally-produced wind waves are generated very quickly, within an hour or so, and provided the wind is steady and the fetch of sufficient distance, the longer it blows the longer the wavelength.

The height achieved depends on the strength of the wind, and up to a certain limiting distance it increases with fetch. So, for instance, a wind of 10 knots blowing over a distance of at least 8 kilometres will produce waves about 23 centimetres high after about 2 hours. If it goes on blowing at 10 knots an equilibrium (maximum) height of 50 centimetres will be reached in about 6 hours, so long as the fetch is at least 40 kilometres and the depth greater than 10 metres. More examples of the heights of newly generated waves are given in the table below. To avoid the higher waves you should

How the size of newly generated wind waves varies according to the strength of the wind and how long it has been blowing, subject to the fetch and depth being greater than the minimum values shown.

WIND		WAVE			
speed kt	time blowing	height cm	length metres	min fetch	min depth
10	2 hours	23	6.9	8km	3.5m
10	6 hours	50	20.2	40km	10m
20	5 hours	100	31.6	40km	16m
35	5 hours	200	56.2	50km	28m
35	20 hours	600	243	430km	122m

The maximum wave height which can be reached for the same wind speeds given sufficient time, fetch and depth.

WIND	WAVE			
speed kt	max ht cm	reached in hours	fetch km	min depth metres
10	60	8	60	15
20	250	16	240	60
35	750	26	700	170

stay close to a windward shore or in the lee of an island, where the fetch is a minimum.

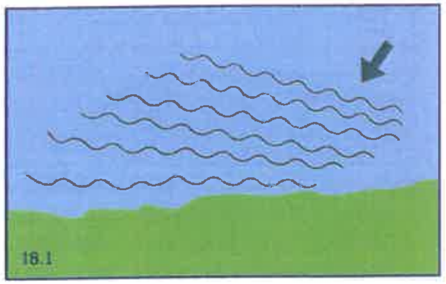
Angle between wind and waves

The angle between the wind direction and the wave front makes a significant difference to a boat's speed through the water, particularly when beating. For the same reason that the surface wind is backed from the pressure gradient wind – friction upsetting the balance of pressure gradient and Coriolis forces – so the wave front makes an angle of a few degrees back from that of the wind producing it in the Northern Hemisphere, making port tack the faster. It is veered in the Southern Hemisphere, where starboard tack is therefore the faster.

However, the wind often changes while the waves are being generated. For instance, during the first few hours of the generation of a sea breeze – with the wind veering some 60 degrees or so – there is a significant angle between the wave front and the wind, and while port tack may be preferable in regard to speed through the water, you will be headed by the veering wind and in the Northern Hemisphere starboard tack is likely to give the maximum benefit to windward. Similarly on the passage of a front or trough of low pressure, a veer in the wind will produce a second set of waves and the sea will become confused. In the 1979 Fastnet storm the wavelength was short both ahead of and behind the cold front because the wind, though very strong, had not been blowing for more than a few hours. The resulting sea was notably confused and dangerous.

Wind and current

A current, whether tidal or not, makes a significant difference to the wavelength while the height may also increase (see pages 70-71). A current running with the wind increases the wavelength, the sea becomes flatter and sailing easier and more comfortable, even in a strong wind. A current running against the wind shortens the



wavelength and the waves become steeper. A strong wind opposing a strong current produces very steep and dangerous seas which are the subject of the next chapter.

Refraction at a shore

When waves approach shallow water they are refracted. Once the depth of water drops to less than half the wavelength, the shallower the water the slower the waves travel. So the wave front bends until it becomes parallel to the shore (Figure 18.1).

Water temperature

The character of newly-formed wind waves depends on the temperature of the water at the surface compared to the temperature lower down. If there is a 'slippery' layer of relatively warm water on top of cold the waves will be generated in the warmer water alone, at least to start with, until the waves produce enough 'mechanical' mixing to involve the water lower down. Many are the times when sailors are surprised to find short, steep waves characteristic of shallow water appearing on the surface of deep water. This is because they are being generated in a surface layer of warm or fresh water, perhaps only a metre or so deep, without involving the water lower down.

Swell waves

Larger swell waves require an adjustment to sailing tactics because of the significant differences in boatspeed achieved between the crest and trough of each wave (described well by Lawrie Smith in *Helming to Win* in this

series). Also, swell waves are often large enough to obscure the marks for a good deal of a race, circumstances in which it is essential to have practised using your compass for navigation. A swell height of some 2 to 3 metres was experienced offshore at Acapulco, site of the sailing events of the 1968 Mexican Olympics. Navy ships had to be stationed near the course marks which were out of sight for most of the time as the Pacific swells rolled by.

The large swell waves generated over the major oceans contain a great deal of energy. Their production takes several days of sustained wind, and as a rule of thumb their decay takes the same sort of time. Typical values of length and period for waves generated in the Trades are 200 to 300 metres and 12 to 16 seconds. Such waves provide the excellent surfing conditions found on coasts bordering the Atlantic, Pacific and Indian Oceans.

As they approach a shore waves always become steeper when the water depth becomes less than 1/25th of their distance apart – 1/25th their wavelength. In the case of swell waves this occurs in water deep enough for sailing, making sailing near a lee shore potentially difficult and sometimes dangerous.

Waves as weather predictors

It is useful to recognise that the longer swell waves travel faster than the shorter, locally produced waves; so when they travel ahead of an advancing depression they give advance warning of its approach. Thus the arrival or absence of swell provides a clear distinction between, for instance, an approaching thunderstorm and a deep depression. A threatening sky with increasing black clouds and rain cannot be part of an existing large wind system if there is no swell propagating forwards from it, so any wind associated with it must be temporary. Equally, increasing swell from the direction of advance of the storm clouds suggests an approaching depression with an area of strong winds coming your way. If there is a swell which has been present for some time – a few days – without significant change the interpretation is doubtful, for instance the depression may be advancing, but very slowly.

'Freak' waves

Oceanographers usually define the wave height on any area of water as the height of the one-third highest waves, which they call the 'significant wave height'. You may see this term used on a regatta notice board. Some waves will always be smaller than the significant height and some will be bigger. It is also normal to experience a range of wavelengths and periods, with waves moving at different speeds and in different directions, continually overtaking one another to produce a mixture of larger and smaller waves. Every seventh wave is popularly supposed to be bigger than the other six, and statistically you can ascribe dimensions to the '1 in a 100' and '1 in a 1000' waves, and so on. In fact a wave twice the significant wave height must be expected every 2000 waves. So, wherever you sail you must expect to experience a wave bigger than the rest. Call it a freak wave if you like, but be prepared.

Calm conditions

Ripples here and there are usually evidence of fleeting puffs of wind. Sometimes one area of water appears particularly flat while another nearby seems to suggest the possibility of a breath of wind. However, there is another possibility – water movement. Where water is subsiding downwards the surface generally appears relatively flat, sometimes even when there is a faint breath of wind. When upwelling is present the water surface is likely to be slightly rippled. Wind or no wind, it is also worth considering what horizontal movements in the water may be indicated by its surface characteristics, an outward movement from an area of upwelling, a convergence into an area of subsidence.

19 Dangerous waves

It is taken for granted that tropical storms (variously known as hurricanes in the Atlantic, typhoons in the Pacific and cyclones in the Indian Ocean) must be avoided. Indeed, no one would doubt the wisdom of avoiding tropical weather systems in which the winds exceed 100 knots. But in fact the world's most dangerous seas are where there is a high frequency of a strong current opposing a strong wind. A strong current on its own has few safety implications except in shallow water and influences only the passage time. But a strong current with an opposing strong wind may be lethal, as evidenced in the 1998 Sydney - Hobart yacht race. The subsequent detailed report on this race by the Cruising Yacht Club of Australia analyses the circumstances in graphic detail. Studying this document leads to the conclusion that a vital element in the pre-race briefing for an ocean race of this sort, is information on the exact location and strength of any ocean current which may be present or expected.

The 1998 Sydney-Hobart storm

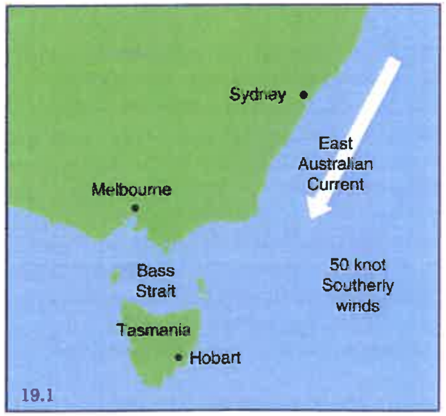
When the forecast storm emerged from the Bass Strait on 27th December with winds of 50 knots, 115 yachts were spread out east-west and north-south with some 80 miles separating the leaders from the tail-enders. A total of 71 retired. None of them probably knew the precise position of the centre of the south-going East Australia Current or the large eddy between 38 and 39 degrees south. Yet such information was crucial for anyone looking for smoother water. Some of the 71 were almost certainly just to the east of the 4 knot central core of the current, and as they turned west for the New South Wales coast, sailed into impossibly steep seas. They would have fared better heading east into slacker current and smoother water, as did those to the east of the central core who stayed on course for Hobart. (Figure 19.1)

Wave heights experienced

Yachts reported wave heights reaching 15 to 20 metres during the race, values which are in good agreement with the theoretical expectation. Assuming a wind speed of 50 knots, a fetch of 200 kilometres and water deeper than 200 metres, the standard formulae predict a significant wave height of 9.8 metres, and a maximum of 20 metres. Nothing too unusual, and frequently met in the Southern Ocean.

Wave steepness

Waves propagating from an area of no current into a steady current are modified. The wave period stays the same but the wavelength changes. Waves on an opposing current become shorter and steeper; waves on a following current become longer and less steep. The shorter waves also increase in height, which means that their steepness increases more than for longer waves. The above table relating wave steepness to wave period for a 50 knot wind and an opposing 4 knot current has been prepared by Dr Judith Wolf of the Proudman Oceanographic Laboratory. Note the dramatic increase in steepness and height for short period waves. In fact, quoting Judi Wolf, 'the waves themselves cannot survive, but merge into a boiling cauldron of confused sea.'



19.1

Wave period (seconds)	Undisturbed Wavelength (metres)	Wavelength On opposing current (metres)	Potential % increase in wave height	Potential % increase in wave steepness
15	348	285	17%	42%
14	303	244	18%	47%
13	267	211	20%	52%
12	224	173	23%	59%
11	189	142	26%	68%
10	156	112	30%	80%
9	127	87	36%	98%
8	100	64	44%	125%
7	77	44	59%	177%
6	56	29	94%	307%

20 Weather routeing

There is nothing mystical or magical about weather routeing. It is simply making sure that at every stage of a race, however long or short:

- You have not overlooked any available and relevant weather information and,
- You have used it to find the quickest way to the finish.

The key word here is 'relevant'. There is little point in being able to download megabytes of fancy weather charts for a two hour harbour race in a dinghy. You need to know the weather forecast, the tides and currents, and how the wind behaves around the bay using the techniques described in earlier chapters.

Short course races

On a championship course you have to do your own weather routeing. Starting with the best and latest shore-based weather information you think through how the shape and topography of the coast and variations in water temperature are likely to influence the winds experienced on the first beat to windward. At the same time, observing the minute-by-minute evolution of the wind and weather, you operate like an on-board computer, judging at every stage of the race which is the best way to go.

The same applies in a typical short offshore or inshore race. You will always have a better appreciation than anyone onshore of what the wind is doing in the short term, particularly the bends, bands and eddies. And the more you appreciate and understand the ways of the wind within the frameworks presented in the preceding chapters, the better your judgement will be.

Longer Offshore Races

So what about the longer offshore races: the Fastnet, for instance, or the Sydney-Hobart? The majority of large ocean-going yachts have the ability to 'log on' and download the latest charts or forecasts from a shore-based meteorologist or router. However, on any yacht you should be able to create a useful forecast for yourself for your area of the ocean given that you have the basic equipment, including the ability to receive weather broadcasts by radio and fax and a correctly-calibrated barometer / barograph so that your observations can be integrated into the weather map.

One point to remember when using ocean forecasts is that there is very little data available to the forecaster ashore. Take, for instance, the leg from Bishop Rock to the Fastnet Light. The chance of the forecaster ashore having a single ship observation between the Scillies and Southern Ireland is remote – in other words you know more than they do! In a light wind race such as in 1981 and 1991 a forecaster on shore could not have elaborated on their general forecast for sea area Fastnet without weather observations from the yachts. Do not hesitate to use your own observations of wind and pressure to make adjustments to the isobars on the appropriate weather maps. (See *Weather at Sea* for more detailed guidance.)

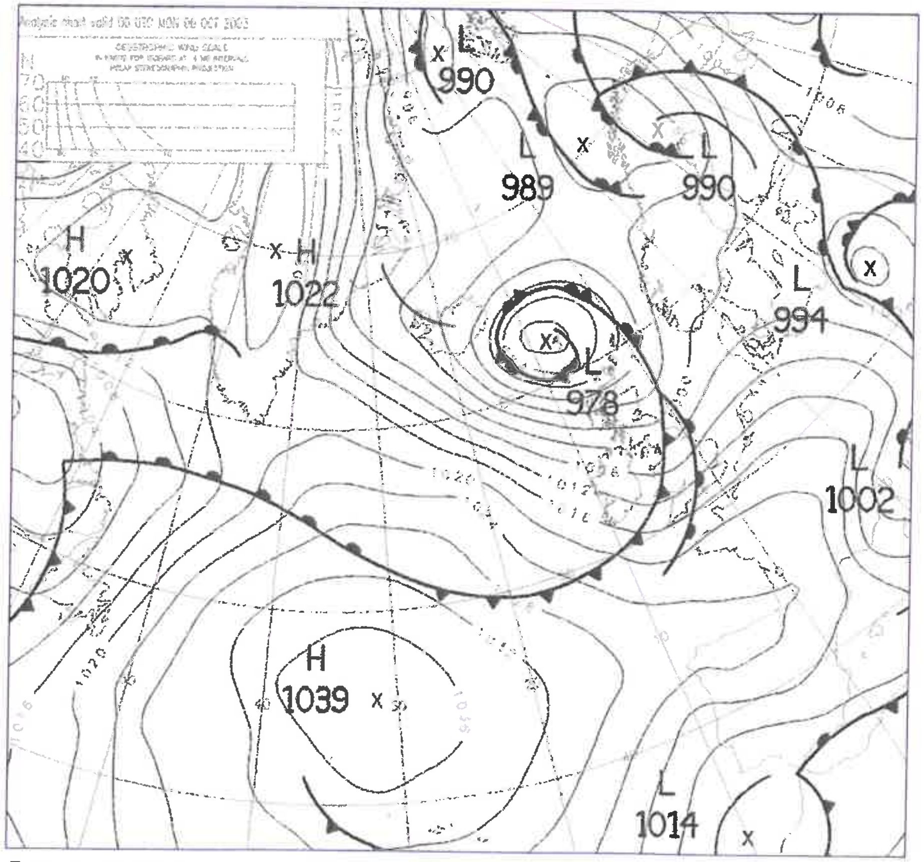
Ocean and round-the-world races

This is where weather routeing comes into its own. Long races require weather knowledge on the synoptic (large area)

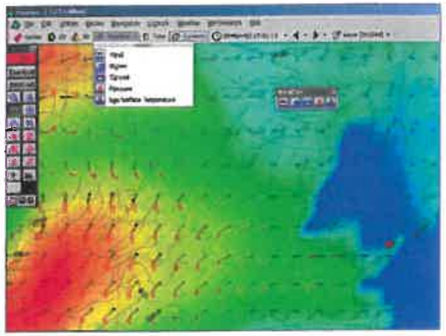
scale, as opposed to knowledge of coastal winds on a local scale. Ocean racing yachts and their skippers, from the ARC to the Volvo, now depend on the up-to-date information they receive by satellite. Some races allow shore-based routeing by a meteorologist, but more often it is the skipper or navigator on board who has to decipher the available information in order to route the boat via the fastest track. Routeing is about strategy. The navigator must ensure that the yacht is sailing not necessarily on the shortest route, but on the fastest point of sail and, ultimately, on the best VMG (Velocity Made Good).

In its simplest form weather routeing during an ocean race means making sure that you keep on the side of the lows and highs where the winds are the most favourable. Crossing the Atlantic from the east to west, for instance, you will want to keep to the north side of the lows or the south side of the highs, and avoid the westerly headwinds in between.

Mari Cha IV's record breaking attempt to cross the Atlantic from west to east in October 2003 saw their navigator send them north of the Azores high to 53 degrees north, rather than taking a



Example of a synoptic chart.


Example of a GRIB file.

straight line route between Newport, Rhode Island at 40 degrees North to the Lizard Point in Cornwall at 50 degrees north. This enabled the boat to sail on a fast reach almost the whole way across, with no headwinds, as they travelled through the south-westerly veering westerly and finally north-westerly winds as they approached the southern Irish sea.

Modern Round the World race yachts can travel at speeds of 15 – 20 knots or more, which enables them to sail from one weather system to another and so remain in the most favourable winds. For slower yachts, which mostly travel at a slower speed than the weather systems, weather routeing is vital to avoid getting trapped on the wrong wide of a weather system.

The race

On board electronic, computing and satellite receiving systems have propelled onboard routeing to the forefront of ocean sailing and racing. With the Internet there is now almost the same amount of information available to a meteorologist or navigator on board a boat as to a shore-based meteorologist. A disadvantage to receiving weather information on board is the time spent online and subsequent cost of downloading the information.

One way of receiving weather forecast data on board is via GRIB (GRIdded Binary) files, which is a compact format of data that needs computer software to display it. Computer programs allow weather routeing to be carried out using this high-resolution wind, wave and tidal data.

Any system of routeing can only be as good as the information available in the first place, and onboard computer routeing can suffer from false confidence in the equipment. But there will always be uncertainties and someone, somewhere has to decide.

Preparation

While there is no substitute for on-the-water race experience, it is well worth taking time out to explore historical weather records for the appropriate ocean areas and time of year. Particularly useful is the *Admiralty Pilot*, which contains a digest of every log of every ship in the Royal Navy over the past 200 years. Only a few paragraphs are devoted to weather. Also of considerable benefit is a visit to the Met Office archives or the internet. Spend a few hours thumbing through the 12-hourly sequences of Hemispheric weather maps for the months of interest, following in each year the development, decay and movement of all the lows, highs, fronts, troughs and ridges, and get a feel for what is typical – and, to some extent, what is not.

One thing you will notice when browsing through past sequences of weather maps is the extent to which each year tends to demonstrate a particular weather 'mood', with a considerable degree of repetition of the development, movement and decay of a 5 to 10 day sequence of weather systems. This underlines the importance of following the weather over a period of at least two or three weeks as an essential part of your pre-race preparation, thus getting a feel for the particular weather mood you are likely to experience.

21 Which sails?

Critical to winning a race is choosing the right sails and, in some classes, the right mast. Too much playing safe may cost you the race; too much risk and you stand to lose the sail or mast or both. Your sensible application of all available weather and wind information is likely to pay off handsomely. Top priority must be a best estimate of the wind strength you will experience during the race, not only the maximum but also the mean. Don't leave this to the last minute. Listen to as many forecasts as possible for several days beforehand to get a feel for the correspondence between the forecast and the actual local wind. Try to judge the reasons for the differences from the forecast: sea breezes, cliffs, islands, water temperature, etc. Keep a log of the most significant features on the weather map so that on the day of the race you know which way the lows and highs are moving along with their attendant troughs and ridges. You may be surprised at how much more confident you are in the forecast for the race having all this information in the back of your mind; a confidence which will extend to the detailed deductions you will need to make on the day itself regarding sea breezes, wind bands, gustiness and so on.

Also make a practice of looking at the clouds, particularly the lower ones, and judging their speed in relation to the wind you observe on the water. Take a compass bearing on their movement, remembering that for clouds at a height of 300 to 600 metres or so the direction of movement is about 15 degrees veered (Northern Hemisphere) from the wind on the water. If you are based some few kilometres inland from the racing area your observation of the clouds will tell you a lot about the wind on the nearby water. This is particularly important early in the day when the near-surface air over the land is typically cool and stable and the wind light or calm.

Will the wind speed increase or decrease?

This will depend on whether or not there is a:

- Change in pressure gradient
- Change in temperature
- Development of a sea breeze
- Change in tide
- A band of stronger or lighter wind somewhere on the course

Change in pressure gradient To judge whether the pressure gradient is changing refer to your weather maps – the latest 'actual' and the latest 24-hour forecast. A rough and ready guide is given in the table below:

Wind increasing	*Wind decreasing*
Depression approaching	Anticyclone approaching
Trough approaching	Ridge approaching
Anticyclone intensifying	Depression filling
Depression deepening	Anticyclone weakening

Keep an eye on the lower clouds; are they speeding up or are they slowing down?

If so this change will be reflected at the surface; but remember that an important indicator of a sea breeze about to start is a slowing down of low clouds moving offshore. Are the clouds generally increasing – a trough approaching; or decreasing – a ridge approaching? And your barometer? A rapid fall of pressure, and often a rapid rise, indicate increasing winds.

Change in temperature On inland waters there is a marked change in wind speed during the day due to change in land temperature. The wind is at a minimum in the early morning when the surface temperature is lowest and the air most stable; and at a maximum in the early afternoon when the surface temperature is at its highest, and the air most unstable. This is true also of coastal waters when the wind is offshore – but then the most important factor is the sea breeze.

Out at sea there is often a small change during the day. A rise in temperature of a degree or so between morning and afternoon will give a small increase in wind – perhaps a knot or so.

When the gradient wind is onshore other changes occur – see Chapter 9.

Development of a Sea breeze
Criteria for judging the development of a sea breeze are given in Chapters 7 and 8 (Chapter 12 for the Southern Hemisphere)

Change in tide somewhere on the course
Tide against wind results in a relatively rough sea and greater surface friction, therefore a lower true wind speed. Tide and wind in the same direction means a smoother sea, less surface friction and a stronger true wind.

Band of stronger or lighter wind
This will relate to :

- An island upwind – see Chapter 3
- A headland upwind – see Chapter 3
- Wind direction nearly parallel to the coast – see Chapter 3
- A boundary between water of differing temperatures – see Chapter 4

Wind shear and weight of wind

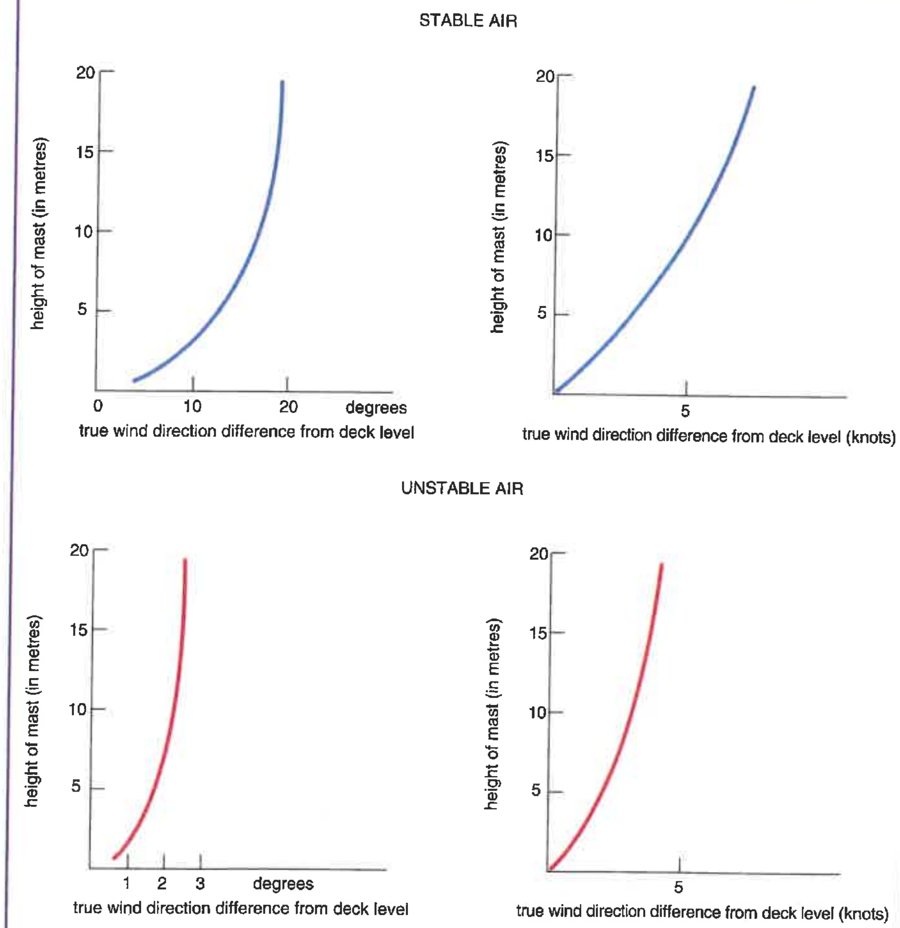
We saw in Chapter 2 that friction at the surface modifies the direction and strength of the wind compared to higher up. This modification is most marked in the lowest few metres, in fact between deck level and the masthead, and is highly dependent on the stability of the air. Figure 21.1 shows typical variations of wind speed and direction with height in the lowest 20 metres as observed on an instrumented fixed pole over Lough Neagh.

In unstable air, when air warmed at the surface is continually rising to be replaced by colder air from higher up, the change in wind speed and direction up the pole is small, about 5% and 1.5 degrees. In stable air when there is no overturning the difference between readings at the top and bottom of the pole was observed to be as much as 300% and 20 degrees or more. So in stable conditions you need a large amount of twist in your sails on starboard tack and very closed sails on port. In unstable air the leeches can be much straighter. Day to day variations in wind shear are particularly noticeable when windsurfing.

A good deal of mystery tends to surround the concept of 'weight of wind'. Time and again one hears the comment after a race that there was more (or less) weight of wind. Some have tried to attribute the variations to differences in the density of the air, or in the water vapour content. But although the density does vary and the water vapour content rises and falls, these variations are nowhere near sufficient to account for the large changes experienced in the 'weight of wind'. They are due to variations in wind shear up the mast. Using the comparisons illustrated in Figure 21.1 for the wind speed change up the mast in stable and unstable air, the difference in heeling moment for the same wind speed over the deck is over 50%.

Your judgement regarding the 'weight of wind' depends on your reference point: whether you are observing the wind at masthead or deck level. Judged from the masthead anemometer reading there will appear to be much more weight in the wind in unstable air, when there is relatively little change in speed right down to the deck, than in stable air when there is a marked decrease in speed downwards to the deck. If however your reference point is the wind on your cheek at deck level, the weight of wind will appear much greater in stable air when the relatively much stronger wind at the masthead will provide the heeling moment.

Also important, though not in low latitudes, is the shear in wind direction, which is due to the earth's rotation. This falls to zero at the equator.



21.1

22 At the regatta

Where to get weather information

Most regatta managements provide weather information for a race series. Pinned on a notice board somewhere you will probably find an 'actual' or analysis weather chart for midnight or 0600 UTC on the day of the race and a forecast weather chart for 12 or 24 hours later. Also supplied may be a written forecast for the race area, commonly the coastal and /or shipping forecast issued by the National Meteorological Service.

Fax, telephone and radio weather services may also be accessed. Details (for Europe) of numbers, frequencies and times are given in the RYA booklet G5, *Weather Forecasts,* along with an international weather vocabulary. G5 also lists Internet weather sites providing forecasts in text, chart and wind arrow formats. Website addresses are too numerous and constantly changing to be listed in this book, but a general search for weather in your local sailing area should produce plenty of choices to select from. National weather service and local sailing club websites often have links to weather websites.

Is the weather forecast useful?

It is not unusual to hear a frustrated helmsman blame the forecast for a poor position at the windward or leeward mark, and indeed there is no better scapegoat. And you are right to ask whether a standard forecast or even a specialist forecast for a race area is of much help. Occasionally, of course, it will be dead right and there will be someone who has believed it and won. But what about on average?

The weather forecast is a vital piece of information for every sailor in every regatta. Its value lies in the background information which it provides: information which will enable you to judge the likelihood, position and character of bends, bands and shifts in the wind. In fact you cannot apply the information in Chapters 2 to 19 unless you know the direction and strength of the gradient wind and how it is expected to change – information that is the basic ingredient of every forecast. But beware of treating a forecast as though it is 'ready for immediate use'. For one thing, many forecasts are describing the weather over a large area and are not prepared specifically for the local area and time of the race. A land area forecast is not designed for the inland or coastal sailor, nor is a shipping bulletin, but most forecasts contain some useful information, and for the majority of regattas you have to tune in to whatever weather information is available and distil what you need to know.

Another thing to guard against is the blind application of information given about movements of major systems such as fronts, troughs and ridges. The chance of one of these crossing the area during a race is small, and the chance of predicting the time of an associated windshift to within 20 minutes, or getting it right on a particular beat, is almost nil.

The weather is often an overlooked or only partially-studied aspect of sailing, it being assumed that it is too unpredictable to allow one sailor to use it consistently to advantage over another. But with practice the weather, deduced from the theoretical tools in this book added to the local forecast, could prove to be that added extra which puts you ahead of the rest.

Can anything be gleaned from satellite pictures?

A copy of the latest picture from a weather satellite may be displayed or included in a handout. This helps to give credibility to the diagrammatic weather map; you can see for yourself that there are real swirls of cloud – depressions – and long, broad bands of cloud – fronts. But the pictures lack the resolution necessary to tell you anything useful about local cloud structures, while to deduce anything about their associated winds requires specialist expertise and a great deal of practice. So the answer is "no" – but they are nice to look at!

The importance of your own observations

It is always amazing how many sailors either rely on what they are told and ignore what they can see for themselves, or rely on what they can see happening before a regatta and ignore the forecast and the indications of change. Your own observation is a piece in the weather jigsaw, which is likely to be unique to you. It may not be available to the forecaster if they are operating from a remote station. Your observations are weather facts, and every forecast is based on the facts about the weather at the time it was written. Never throw either the forecast or the observation out of the window. The more you practise putting them together the better will be your judgement in a race.

During the previous few days

1. Follow the weather on the scale of the weather map

Note the movements of depressions, fronts, troughs, anticyclones and ridges from day to day, using the charts online, in the daily newspapers or on television. Get a feel for how fast things are developing and for the way the pressure gradient wind is changing from day to day in both speed and direction. The internet is a useful tool in this respect as a movie can be played which animates the charts and brings the weather alive.

2. Follow the weather on the small scale

If you are preparing the boat near the regatta area, practise observing the clouds and the wind variations, getting a feel for the changes as they occur. Try to distinguish events that are due solely to changes in the gradient wind and those which are due to local factors.

3. Study the course

Think out the likely sea breezes for different gradient wind directions, (a topographic or simple road map will help to give the local lay out of the land). Consider what effects the land will have on the wind if it is blowing offshore. Are there islands, bays and other features to influence the wind? What is the water temperature? Is it uniform? Are there any rivers – sources of fresh water nearby? Look up the tides and the general currents for the area.

The morning of the race

Ask yourself these questions;

- *What is the gradient wind doing?* What is its direction? What is its speed? How does it tie in with the movement of the pressure systems over the past few days?
- *What is it forecast to do over the next few hours?*

  If you have no access to a weather map you will have to judge the gradient wind from the forecast surface wind: assume that it is in approximately the same direction if the forecast uses an eight-point compass, or veered by 15 degrees if you have more detail.
- *How are the low clouds moving?*

  Take a compass bearing on their direction and judge their speed. Does their movement fit the forecast?

  If it does not, then either mountains or valleys are interfering with it (see page 44) or you listened to the wrong forecast.
- *What is the surface wind at present (i.e. early morning)?*

  Is it the remains of a night land breeze? (See Chapter 11). Has it been killed by a night-time temperature inversion?

(see page 47). Or does it agree with the gradient wind: 40 degrees or so back from it over land and much lighter early in the day? Details of land breezes and other local winds are not normally covered in a standard weather forecast. Refer to Chapters 11 & 13 to sort them out.

- *What wind is forecast over the water? Does the forecast appear to have taken into account coastal influences on the wind?* The standard sea area forecast for shipping does not normally include coastal effects, but it provides essential background information which you can easily translate into what the gradient wind is expected to do. The rest you may have to work out for yourself.
- *Is the wind nearly parallel to the coast?* If it is, you must consider the divergence or convergence of streamlines (see Figures 3.6 and 3.8).
- *Has the gradient wind an offshore component – i.e. is it in Quadrants 1 or 2?* If it is less than 25 knots and cloud is thin or broken expect a sea breeze (see Chapters 7, 8 or 12). If it is strong or you are racing before or after the sea breeze expect a bend or standing waves (see Chapter 3 or 6).
- *Has the gradient wind an onshore component – i.e. is it in Quadrants 3 or 4?* See Chapter 9 or 12 for what happens when the land heats up, Chapters 3, 11 and 12 for other times.
- *Are there islands upwind? (See Chapters 3 or 6).*
- *Is the air stable, with flat low cloud or hazy – or unstable, with cumulus cloud and good visibility?* Think of gusts and lulls (Chapter 5) or possible bands (Chapters 4 & 14).
- *Are showers likely?* See Figure 14.2 for wind associated with a raining cloud.
- *Is there a current running?* See flow chart on page 66.

Sailing to the start

- *Observe and record the windshifts.* Note any changes in cloud.
- *Is the cloud dispersing just offshore?* This suggests that a sea breeze is about to appear (see Chapter 8).
- *Is the cloud generally increasing to weather?* This suggests the approach of a trough – see 'lines of cloud' on page 58.
- *Is the cloud developing only over the land?* This suggests a sea breeze building if the gradient wind is in Quadrant 1 or 2 (Chapter 8); other and possibly very different thermal influences if the gradient is in Quadrant 3 or 4 (Chapter 9, 12).

Before the start

- *Is there a bias on the line?*
- *What will the bias be at the time of the start?* See pages 23 and 24 for the timing of gusts and lulls. See Chapters 8 & 9 for guidance on how far the wind direction swings in different situations.

On the first beat

Does one side pay? If so is this due to:

- Features of the land or islands affecting the wind? (Chapter 3)
- The presence of a sea breeze? (Chapters 7 & 8)
- Water temperature variations across or upwind of the course? (Chapter 4)

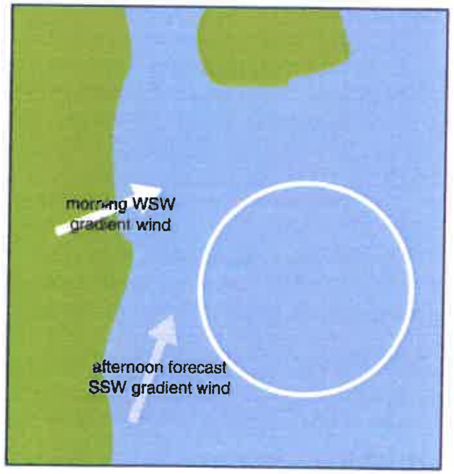
If there is a good reason for one side paying, and you expect that feature of the wind or water to persist, go towards that side next time around. How far you should go towards the layline will depend on how certain you are that the bias is permanent. For instance, if there is an island upwind and no change in wind direction you can be confident that the bands of strong and light wind downwind from the island will continue. If you can find no good reason for the bias then go up the middle next time and play the shifts.

Deduce your own forecast – Example 1

Geography	Flat coast facing east
Race area	Circle 5 kilometres in diameter, 2 to 7 kilometres from the shore
Complications	Island 3 kilometres diameter, 5 kilometres north of race area
Tides & Weather past few days	Tide only – normally no other current. Succession of fronts and troughs moving eastwards. Wind Force 6 previous day
Forecast for area (from internet, radio or TV):	Trough approaching from west during evening; wind south-west Force 2 to 3 backing southerly and increasing Force 5 to 6 by evening. Rain later. Local sea breeze near coast for a time
Weather at breakfast time	Sunny – no cloud
Morning gradient wind	There is no low cloud to indicate the direction of the gradient wind so you must infer this from the 'official' forecast. A south-westerly surface wind over the water implies a gradient wind about WSW
Time of start	1300
Forecast gradient wind in afternoon	Forecast wind backing southerly so the gradient wind must back towards SSW
Likelihood of sea breeze	No mention of sea breeze direction or strength in the forecast but the gradient wind is in Quadrant 1, and although backing a little will stay in the Quadrant. So a good sea breeze expected so long as the land is warmer than the water, i.e. until thicker cloud arrives ahead of the trough
Your wind forecast	Wind south-westerly Force 2 to 3 at first, dying as easterly sea breeze sets in over the race area before midday. Sea breeze at start of race probably ESE Force 1 to 2 increasing and veering to SSE Force 3 to 4. If general increase in cloud then gradient wind will probably take control causing veer to southerly, perhaps up to Force 5 by late afternoon. Full effect of gradient wind will not be experienced near the coast since airstreams on land and water will be diverging

Possible complications

Wind	Island is downwind of race area so it has no effect
Gusts	Sea breeze air normally stable, so no short gust-lull sequence likely. Longer period swings are often experienced in this situation with 'gusts' usually from the direction towards which the wind is changing, in this case a veer.
Current	Water well mixed (Force 6 previous day) so no wind-driven surface current expected. Coastline uncomplicated so no eddies.

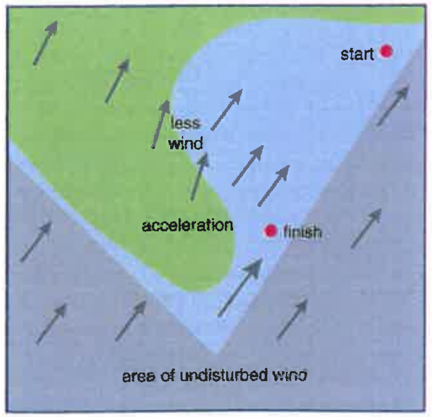


Deduce your own forecast – Example 2

Geography	Flat coast facing south, headland extending south
Race area	Circle 5 kilometres in diameter, 2 to 7 kilometres from the shore
Complications	Headland extending south is high and steep
Tides & currents	Tide and current from river flowing south east.
Weather past few days	Cold front passed overnight last night
General forecast for area (from internet, radio or TV)	Cold front to east, ridge in the Irish Sea building. South westerly Force 4 or 5 decreasing later Force 3 or 4. Sunshine and showers, showers less frequent during the afternoon
Weather at breakfast time	Numerous cumulus clouds, some producing showers
Morning gradient wind	Cumulus clouds moving from 240° at 25 knots
Time of start	1200
Forecast gradient wind in afternoon	Forecast wind decreasing but no gradient direction change
Likelihood of sea breeze	Gradient onshore so no chance of a sea breeze
Your wind forecast	Wind south westerly Force 4 or 5, decreasing through the afternoon. Little gradient direction change expected so looking for local effects caused by the headland; these effects are likely to last throughout the race. Look out for raining and non-raining clouds and their associated wind patterns

Possible complications

Wind	The headland will have a large effect on the wind, with less wind expected in the lee, and more wind to the south east where the wind is accelerated around the base of the cliffs
Gusts	A gusty and shifty wind due to the cumulus clouds, expect downdraughts from the raining clouds
Current	Water well mixed (Force 6 previous day) so no wind-driven surface current expected. Eddies may form around the headland



23 Popular racing venues analysed

This is where it all comes together: the exciting bit, the application of our understanding of the principles described in the previous 22 chapters to the real life challenges of sailing to the next mark in the shortest possible time anywhere in the world. Rather than present an over-sketchy analysis of winds at a large number of sites the following is a fairly detailed analysis of a limited number of the more popular venues and passages, but selected also for their diversity in regard to topography, shape of coast, proximity to rivers, etc.

In all the diagrams the lengths of the arrows are proportional to the wind strength, but no precise relationship is intended.

CHANNEL ISLANDS – WINDS AND WAVES

Steep seas

Interaction between wind and current may make or mar a passage, and nowhere more so than sailing through the Alderney Race or the Little Russel. Changes in wind direction are particularly important, because a swing from blowing with the stream to against it can quickly lead to a dangerously steep sea. The height of the waves depends on the wind speed; the distance between wave crests depends on how long the wind has been blowing and the component of the stream along the wind direction. In the streams encountered around the Channel Islands the difference in wave length between following and opposing winds can be well over 50%.

A gale force 35-knot wind is a comparatively rare event in the Channel Islands in summer, but just imagine what these waves are like when their wavelength is reduced by half in an opposing six-knot stream! Conversely, of course, the apparent calming of the sea when wind and tide are in the same direction and the wavelength is doubled is nearly as dramatic. So two important questions to be asked before setting sail are:

- Will there be a major change in wind direction?
- Will the wind remain strong enough to make the passage under sail?

For the answer to both questions it is necessary not only to take on board the weather forecast, but also to think through the possibility of sea breezes and what may happen if there are showers or thunderstorms about.

Wind direction changes

When the wind is light, Force 1 or 2, the direction is often unreliable. Swings of 40 or 50 degrees or more are common, particularly where there are significant variations in water temperature such as are found between areas of upwelling and sinking water and around overfalls. If the wind has been light for some time the waves will be low and their length is unlikely to be of much consequence, though the difference between a wind with and against the stream will still be very noticeable.

With stronger winds, Force 3 and upward, the large and relatively sudden changes in direction which we need to anticipate are associated with:

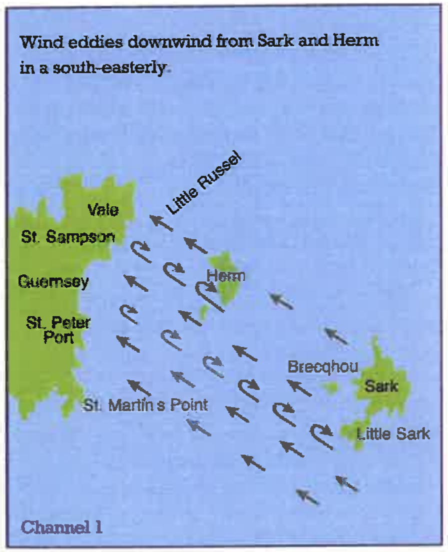
- the passage of a trough (including a front since a front always lies in a trough of low pressure);
- a heavy shower or thunderstorm;
- the arrival of a sea breeze.

They are all very different in character. The first, a trough, is described by meteorologists as a synoptic scale event, in other words a feature of the weather map, and the associated wind changes are always mentioned in the weather forecast. The other two are meso-scale events – on a scale of up to 50 miles or so. They may sometimes be referred to in a standard forecast but are not described in detail. It is up to you to sort out the details.

Wind changes at a trough

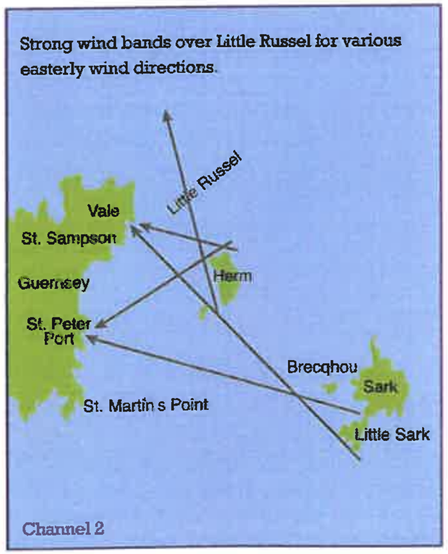
The arrival of a trough of low pressure can normally be anticipated from the forecast. It may be mentioned specifically and its timing inferred from the 'General Synopsis'. Ahead of a trough the wind normally increases fairly steadily, and the waves build to a height and length appropriate to the wind speed. There are also the usual signs of increasing cloud, rain, and falling barometer. The direction change as the trough passes is typically in the order of 30 to 90 degrees, occasionally more, and the new wind lasts for some hours. The largest swings occur typically when a small wave depression moves east up the Channel. Then the wind will suddenly change from southwesterly to northeasterly with the passage of the cold front.

But, you may ask, do troughs turn up all that often in summer? If you look at the statistics you will find that the frequency of troughs passing through the English Channel varies greatly from month to month and year to year. From 1975 to 1999, when the wind was stronger than Force 3, the frequency varied from 10 to 20 occasions per month in winter to between 2 and 10 in summer. August 1976, in the long dry spell, saw only 2 troughs passing, in



Wind eddies downwind from Sark and Herm in a south-easterly.

Channel 1



Strong wind bands over Little Russel for various easterly wind directions.

Channel 2

August 1985 there were 9.

I have not mentioned the passage of ridges of high pressure because, although they bring a large change in direction, it occurs slowly over a period of many hours and in relatively light winds.

Anticipating squalls

A heavy shower or thunderstorm which is not associated with a trough brings relatively transient wind changes. The only herald of the change is probably a big black or bubbly-looking cloud. The wind ahead may be from any direction in relation to the raining or non-raining cloud – sometimes from the direction of its approach, sometimes towards it.

Beware a southwesterly

Within the southwest quadrant there are two points where a strong wind band must be expected in the Race. One originates off the north west coast of Guernsey when the direction is about 235 degrees true; the other off the east of Sark with a wind from about 220 degrees true. In both cases expect an extra 5 knots or so above forecast.

Gustiness – Herm and Sark upwind

All the larger islands contribute to gustiness in the wind whenever one of them is upwind.

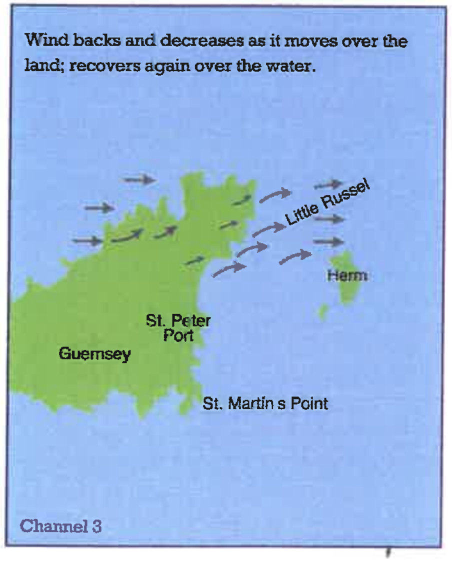
If Sark and Herm were low-lying, their influence on the wind would be due solely to a temporary change in the surface friction, but both islands are high enough to present significant barriers to the wind as well.

The air piles up against the windward coasts and sweeps around and over the headlands, leaving a wind shadow in the lee, and sometimes standing waves as the wind recovers downwind. (Channel 1)

Between north-east and south-east there is some part of the Little Russel where either Sark or Herm is upwind, and their influence is felt. (Channel 2)

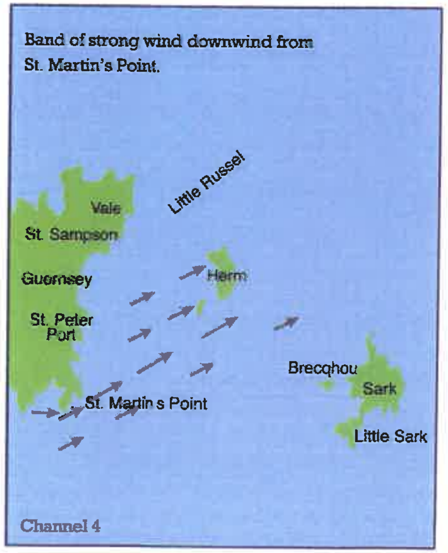
So look for:

- A band of stronger wind extending downwind from whichever northern or southern headland is upwind. The strongest band will come from the



Wind backs and decreases as it moves over the land; recovers again over the water.

Channel 3



Band of strong wind downwind from St. Martin's Point.

Channel 4

southern headland because here the frictional and barrier effects of the island combine. A temporary increase in wind of 25 to 30 per cent is not unusual. Wind bands often extend many miles downwind, and the band off Sark may be just as noticeable as that off Herm.

- A particularly noticeable strong wind band from about 160 °T generated by the south-west-facing coast of Herm (due to 'coastal convergence' – and encouraged by funnelling between Herm and Jethou)
- A wind shadow, more especially downwind from Herm and within a mile of the shore
- Standing waves in the wind, more especially downwind from Herm. The position of the strongest wind – beneath the first trough in the 'wave' – depends on the stability of the air and will be between 1 and 2 kilometres downwind
- A possible wind eddy – most likely in a south easterly – in which there is a temporary reversal in direction for up to 2-3 minutes.

Gustiness – Guernsey upwind

From St Peter Port northwards, Guernsey is fairly flat, and for westerly winds the island effects experienced over the Little Russel are what you might expect downwind from any flat island a mile or two wide. (Channel 3)

As it crosses St Sampson Vale, the wind backs some 20-25° as it moves over the land, then recovers by about the same amount over the water. This applies for all directions between about WSW and NW. Approaching Beaucette or St Sampson harbour, therefore, expect the wind to back through at least 20°, starting from a point two or three miles downwind from the shore.

On a sunny afternoon, when the land is warm, there will be little decrease in strength as you approach the coast, merely an increase in gustiness. At night, however, particularly under a clear sky, the decrease in speed will be very marked. Starting with a wind of Force 3 or less offshore there is unlikely to be enough to stem the tide by the time you reach harbour.

South of St Peter Port the characteristics of an offshore wind are critically dependent on its precise direction. A back or veer of only
2-3° is sufficient to change its strength and gustiness drastically. Standing in or off by another cable can do the same. The main effects are:

- 'Standing waves' downwind from the cliffs with a wind from about south-west to west (Chapter 3 Figure 3.11). The positions of the stronger winds beneath the wave troughs, and lighter winds beneath the crests will be stationary for as long as the direction stays the same.
- With a wind direction in the range 010-240°, a band of strong wind lying along the wind direction downwind from St Martin's Point; a consequence of air piling into the bays on the island's south coast and sweeping past the Point. (Channel 4)
- An area of relative shelter under Jerbourg, punctuated only by a possible band of wind under the trough of a 'standing wave'.

Sea and land breezes

Guernsey is not large enough to cause full-scale sea and land breezes, but it is big enough to give some minor land and sea breeze effects over the Little Russel when the wind gradient is slack. With a light westerly, expect 'holes' in the wind on a sunny afternoon. And on a clear and fairly calm night, weak land breezes down the valleys will give some interesting variations in strength and direction close inshore.

High and low water

At LW the amount of land upwind, whether it is Guernsey or the smaller islands, is up to 15 per cent or so more than at HW. So the effect of the land on the wind – producing

gusts, bands, bends and eddies – will inevitably be greater at LW. At LW springs even some of the lesser chunks of rock become prominent enough to influence the wind in a small way.

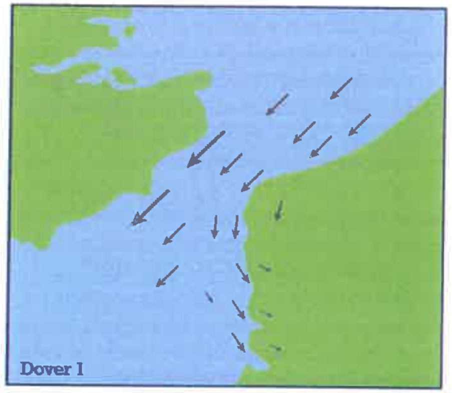
Sea and land breezes on the Guernsey coast are also influenced by the state of the tide. They are only weak, but a breeze at LW is up to a knot or so more than at HW, and in the absence of any other wind this can be useful.

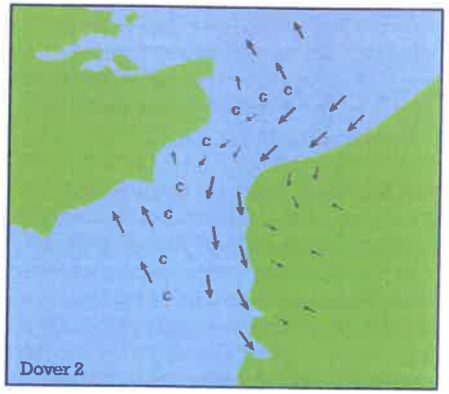
The contrast between high and low water is probably most noticeable in St Peter Port harbour with a westerly. If, for instance, LW coincides with sunset, the cooling of newly exposed areas of mud and rock, along with the rest of the island, leads to a marked drop in the wind.

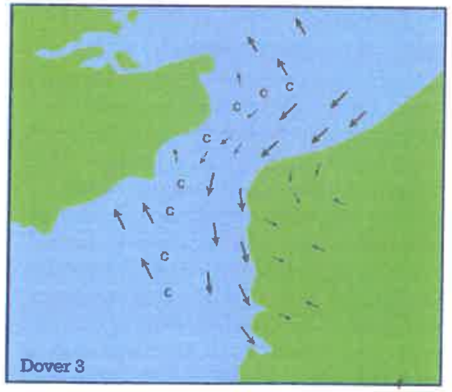
THE STRAIT OF DOVER

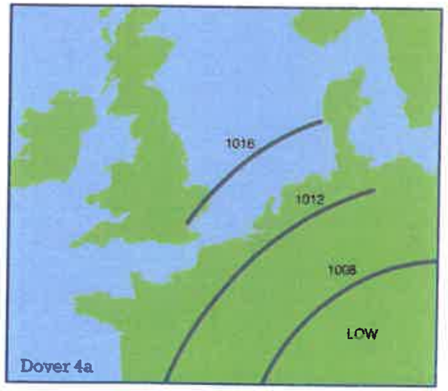
The whole area of the Strait of Dover, from Hastings to Ramsgate on the English coast across to Abbeville to Dunkerque on the French coast, provides a particularly good example of the operation of the sea breeze. There are sections of coast facing most points of the compass so that, whatever the wind direction, there will be found somewhere the essential requirement for a sea breeze - the gradient wind blowing offshore. Wind data for the coastal sites show that in the six summer months the great majority of offshore winds in the early morning are followed by sea breezes in the afternoon.

- South of Cap Gris Nez the coast faces west, the sea breeze starts as a westerly and

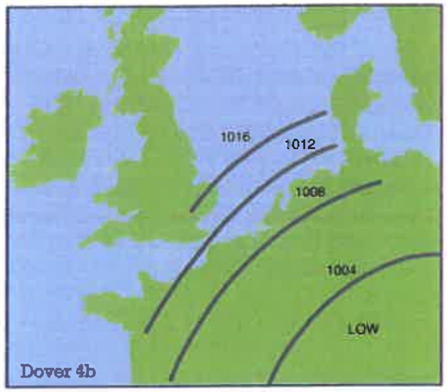

Dover 1


Dover 2

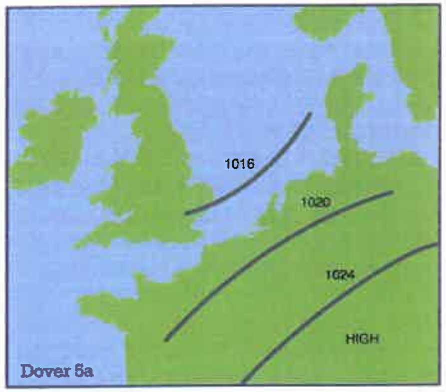

Dover 3



Dover 4a



Dover 4b



Dover 5a

veers to NNW.

- Going round to Calais and Dunkerque the coast faces north, the sea breeze starts as a northerly and then veers to ENE.
- On the English side the coasts face between east and south and the sea breezes start as easterlies or southerlies, subsequently veering towards south and west respectively.

Sea breezes near the coasts

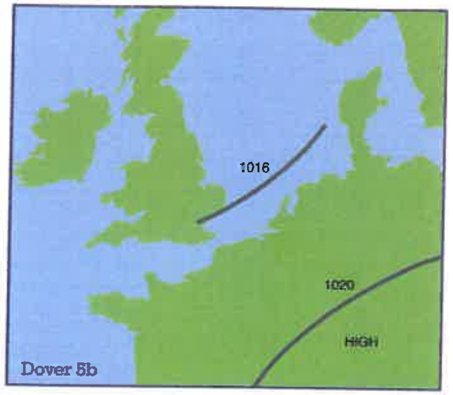
Where the hinterland is deep, and there is a long stretch of relatively straight coast, as from Boulogne southwards, a strong sea breeze is experienced. If the morning offshore wind is less than about 15 knots it drops to calm by mid-morning, followed by a gentle onshore breeze which increases steadily to near Force 6 close to the coast by mid-afternoon. The strength decreases seawards until the calm zone is reached some 30 to 50 kilometres off.

North of Boulogne the bend in the coast at Cap Gris Nez restricts the occasions of a strong sea breeze to when the gradient wind is offshore right around the coast, i.e. to when it is between east and SSE. With a northeasterly gradient wind - onshore north of Cap Gris Nez and offshore to the south - the wind will bend around the cape (Dover 1) but will not reach full sea breeze strength for 30 kilometres or so along the coast. The restricted width of the Strait close to Dover and Calais also prevents sea breezes north of Boulogne from reaching their full potential (Dover 2).

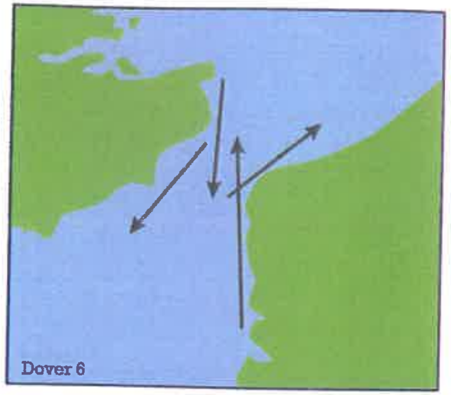
On the English coast the strength of sea breezes east of Dungeness is restricted by the width of the peninsula. To reach its full potential a sea breeze needs at least 50 miles of land room and at least 30 miles of sea room. After about 2 to 3 hours, as soon as the advancing sea breeze reaches the North Downs and the cooler air coming off the Thames estuary to the north, it starts to die. The offshore wind may then return, particularly if the gradient is Force 3 or more. In the case of a northerly, Folkestone is about the eastward limit of the sea breeze, and as the sea breeze dies the northerly spreads back westwards from the east coast (Dover 3).

Sea breezes in the Strait

Sailing through most of the English Channel it is possible to avoid coastal sea breezes by sailing well off - if you wish to. They may reach a distance of 50 kilometres or so offshore by mid- to late afternoon, and the remains of a dying sea breeze cell may be experienced as it drifts down the gradient wind during the evening and night, causing a temporary interruption to an otherwise steady wind. But in the Dover Strait it is impossible to avoid the influence of a sea breeze which is blowing onto the French



Dover 5b



Dover 6

coast, and most sea breezes onto the Kent coast extend much of the way across to France. The main problem is to avoid the calm zone as it moves out from the sea breeze coast. As a rough guide, expect to find the calm zone 15 kilometres off by midday or soon after, and 30 kilometres off by early afternoon.

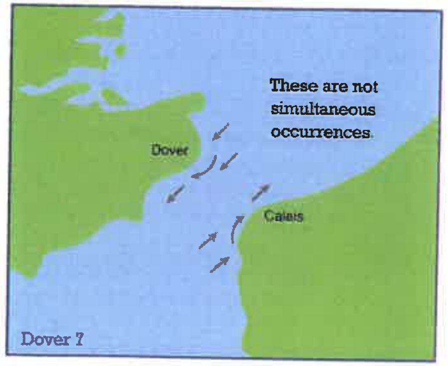
Keeping your eye on the gradient wind

Remember that the sea breeze will develop or continue only if the gradient wind remains offshore. Continual reference to the forecast is important, preferably the forecast weather map. If the gradient wind changes from offshore to onshore during the day, the onshore wind will cease to have the characteristics of the sea breeze; it may or may not increase, it may or may not veer and most importantly, it will not be strongest close to the shore.

Wind changes due to heating of the land

In addition to generating a sea breeze when the gradient wind is offshore, heating of the land causes a fall in pressure over the land, which means a small change in the gradient near the coast. In the area of the Dover Strait the effect of heating of the Kent peninsula is small compared to the effect of heating of the Continent the other side. Heating of the Continent causes the pressure to fall by 4 to 6 millibars. If the pressure is already relatively low over France and Germany, i.e. when the gradient wind is roughly east to northeast, the gradient will strengthen near the coast (Dover 4a and 4b) and the wind will increase by about one force along the coast and up to 15 kilometres or so seaward.

Conversely, if the gradient is westerly, which means relatively high pressure over the Continent, heating will reduce the gradient (Dover 5a and 5b) and the wind near the coast will drop. For other wind directions the addition of an easterly component due to heating of the Continent will mean a swing in direction, a back or veer depending on whether the initial wind is southerly or northerly, and little change in speed.



Dover 7

Another way to envisage this effect of the heating of a land mass is in terms of adding to the initial wind a vector whose direction is roughly parallel to the coast and whose strength is up to about 6 knots, depending on the amount of heating.

Other coastal effects

For certain wind directions there are not only bands of stronger wind near the coast due to the convergence of land and sea winds, but also a considerable amount of funnelling through the Strait which is encouraged by hills and cliffs, especially the Cliffs of Dover. The precise direction for the maximum effect is always fairly critical, a swing of a few degrees either side causing a substantial increase or decrease in the wind. The major wind bands in the area are as follows and illustrated in Dover 6.

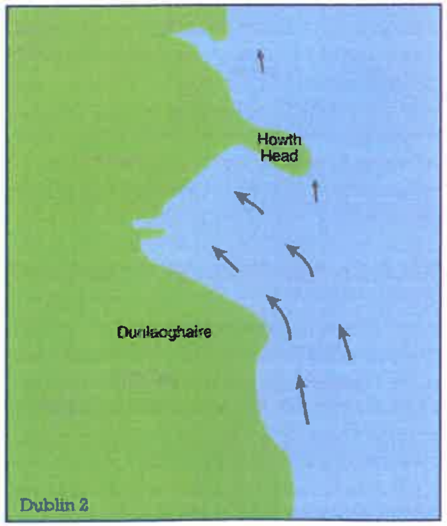
- A direction near 050 to 060 degrees is notorious off Dover, the wind piling into the coast up to Ramsgate, and sweeping around the headland, then onwards in a strong band up to Dungeness and beyond.
- A southwesterly is generally strongest on the French coast, sweeping around Cap Gris Nez and on into the North Sea.
- A southerly causes a strong wind band along the coast from the Somme to Cap Gris Nez, which continues for many miles downwind, and is encountered when reaching eastwards from the Kent coast.
- A northerly causes a strong wind band off North Foreland which drives southwards through the Strait.
- Westerlies and easterlies are subject to some bending near Dover and Calais respectively. As the air piles up against the coast – north of Dover in an easterly, and south of Calais in a westerly – the wind bends around the corner. An easterly is bent towards the north near Dover, and a westerly is bent towards the south near Cap Gris Nez (Dover 7). So, reaching across the Strait in either direction, expect to be headed as you approach the opposite shore.

Dublin 1

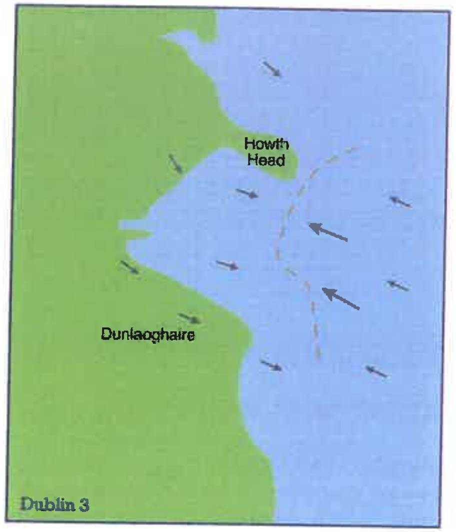
DUBLIN BAY

Gradient wind 180-200 degrees

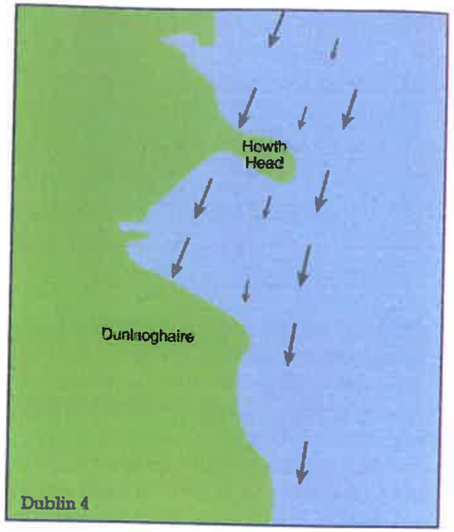
Morning wind on water around 165 ° to 185 °. Afternoon heating of land causes gradient near the coast to back until the isobars are parallel to the shore. Wind over the water swings to about 165 degrees and increases by about 5 knots. Look for a slight bend into the Bay.(Dublin 1)



Dublin 2



Dublin 3



Dublin 4

Gradient wind 120 –170 degrees

Morning wind on water 105 to 155 degrees. Afternoon heating causes gradient to veer until isobars are aligned more to the coast, with 5 to 6 knots increase in speed. Direction on water swings towards but not beyond 165 degrees.

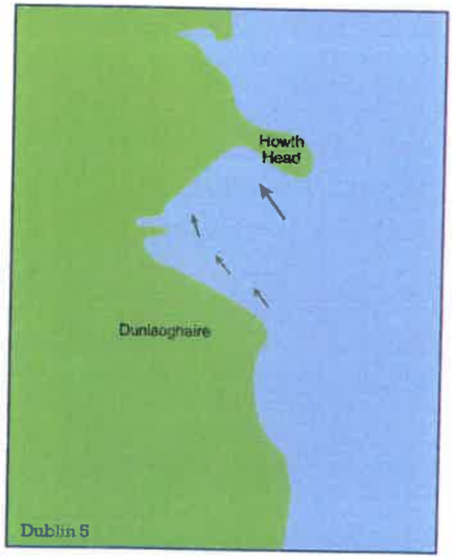
Gradient wind in Quadrant 1, less than 20 knots

Morning wind on water southwesterly. Sea breeze to be expected unless very cloudy.

Wind dies on water from mid-morning with onshore sea breeze starting close inshore, then extending steadily seawards and increasing. Direction swings to the right towards a final value of about 160 degrees, except in the Bay itself where it bends towards the shore to get around the mountains. (Dublin 2)

Gradient wind in Quadrant 2, less than 15 knots

Morning wind on water north-westerly. Sea breeze to be expected unless very cloudy, starting 4 to 8 km from the shore, extending slowly shorewards, more quickly seawards. Shoreward edge of sea breeze marked by thicker cloud and moving erratically; probably making better progress on north side of Dublin Bay. (Dublin 3)



Dublin 5

Gradient wind offshore and over about 25 knots

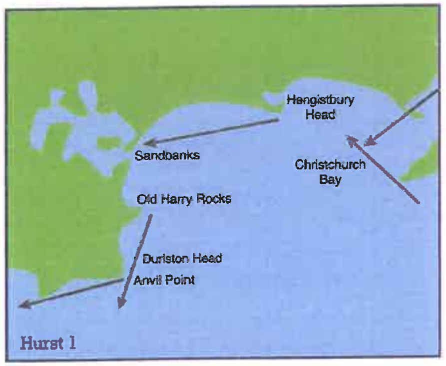
No sea breeze. Heating of the land causes an increase in buoyancy over the land so surface wind increases, with gusts approaching gradient wind speed and direction. Wind near the shore reflects these changes in the land wind. Lulls more pronounced – lighter and more backed – the nearer you are to the shore.

Gradient wind between 360 and 120 degrees

For surface wind between 005 and 025 degrees, expect a band of stronger wind along north coast of Howth extending across the isthmus into Dublin Bay, and another just east of Howth Head. (Dublin 4)

For surface wind between 100 and 120 degrees, expect a band of stronger wind just south of Howth Head with a light band on the opposite side of the Bay. Dublin Bay is just the right size to accommodate a fully developed strong band on one side and a light band on the other (Dublin 5).

Expect afternoon wind to be lighter for directions between north-east and north.

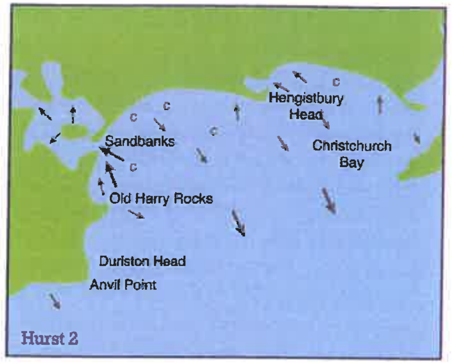


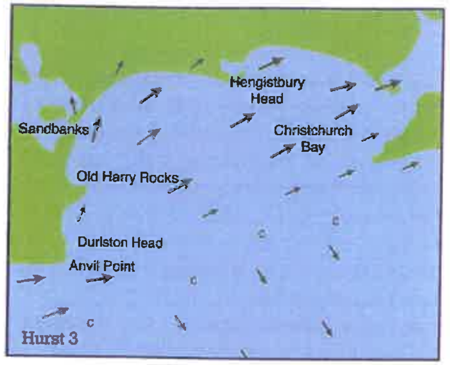
HURST - POOLE

Strong wind bands

The most significant wind bands between Hurst and Anvil Point are shown in Hurst 1. You will find them at any time of the day or night when the wind direction over the water is close to the directions shown:

- From Old Harry to Durlston Head / Anvil Point and thence for 20km or more downwind when the wind direction is around 020⁰.
- From Hengistbury to Sandbanks for a wind near 080⁰.
- From the Needles into Christchurch Bay





for a wind near 120⁰.

- From Hurst across towards Anvil Point when the direction is about 040⁰, this band having been generated along the north-west shore of the Solent.

Sea breezes

The best sea breezes between Hurst and Anvil develop when the gradient wind is from the north-west or north, between about 290 and 360⁰, and less than about 20 knots. Then, if the day is bright or sunny enough to raise the land temperature above the sea temperature, the land wind will die away and an onshore sea breeze will set in. Generally, it starts close to the shore by mid-morning, and then extends steadily seawards, veering gradually until, by early afternoon, there is a south-westerly over the whole of Christchurch bay, Force 4 to 5 near the shore, decreasing as you sail away from the shore.

Hurst 2 shows the typical start of the sea breeze and Hurst 3 the typical mid-afternoon winds on a sea breeze day. The length of the arrows is proportional to the wind speed.

When the morning offshore wind is near the strength limit for a sea breeze, 20 – 25 knots, it is possible sometimes to find two different winds side-by-side, a sea breeze blowing into the valleys and a north-westerly continuing off the higher ground.

PLYMOUTH SOUND

Where the wind is concerned, the most significant features of Plymouth Sound are the cliff-edged headlands guarding the entrance; Dartmoor to the north-east, Bodmin Moor to the north-west; the valleys in between, especially the Tamar and Tivy; and the open sea to the south – the reason for the breakwater.

Breakwater

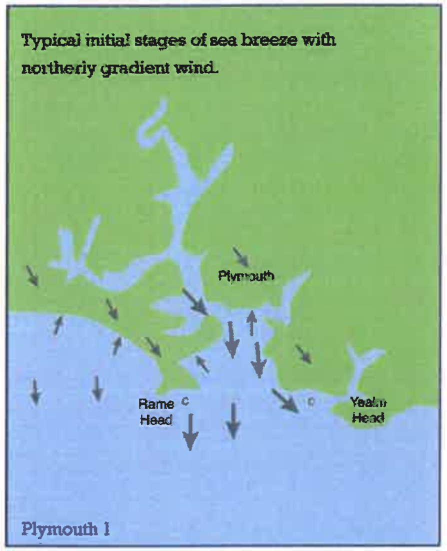
Plymouth breakwater is a significant barrier to the wind at low water, so it is important to expect its influence on the wind to vary with the state of the tide. The general rule for solid barriers is that the wind behind them is disturbed over a distance of approximately 40 times the height of the barrier. Figure 16.1 shows how disturbance varies with distance. Surprisingly, the wind recovers more slowly after crossing a line of trees than downwind of a solid wall. It is also important to note that the behaviour of the wind downwind of the breakwater depends on the stability of the air. If you are racing in the Harbour do not assume that for a given wind direction and speed the general pattern of the wind downwind of the breakwater will always be the same. It will not. It will be totally different in stable air – when it will prefer to go around the breakwater – than in unstable air, when it will be just as happy to go over the top.

Sea breezes

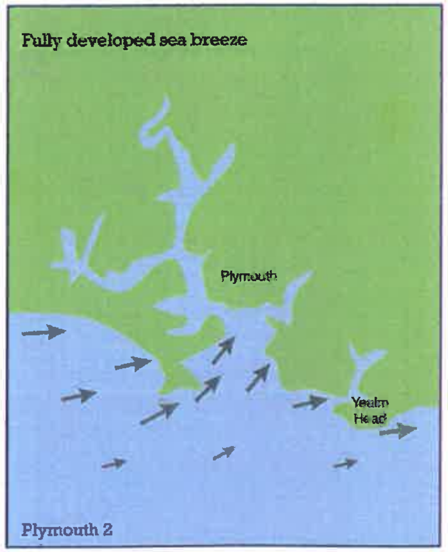
Sea breezes at Plymouth, as elsewhere, obey all the normal rules. Typically, on a bright or sunny morning, the offshore wind dies close to shore and the first zephyrs of the sea breeze begin to blow directly onto the shore. The sea breeze then builds up, penetrating inland, extending seawards and veering.

It is easy to see how this typical pattern fits the coast along Whitesand Bay to the west and Bigbury Bay to the east, and it is true that the best way to envisage a fully-developed sea breeze on an irregular coast is to draw a straight line through the irregularities. However, Plymouth Sound is rather more than a minor irregularity and what happens can be summarised as follows:

- During the developing stage the calm patch followed by an onshore drift of air is found only on those coasts where the gradient wind is offshore, i.e. only on the west and north coasts of the Sound when the gradient wind is north-westerly, and only on the north and east coasts when it is north-easterly. Plymouth 1 shows a typical sea breeze start with a northerly gradient.
- The development of the sea breeze onto the west coast depends also on whether it is high or low water, i.e. on whether the lakes up the Tamar are cool water or warm mud. At high water there is hardly enough land to the south-west of the city to support a sea breeze, and it is fitful until the breeze developing onto the coast further west takes over.
- The direction of the developed sea breeze is roughly westerly off Rame and Yealm Heads – i.e. about 15-20° back from the general direction of the coast – but with a significant bend into the Sounds (Plymouth 2). The main reason for this bend is that, as the sea breeze is relatively stable, air prefers to flow round the high ground rather than over it.
- With a northerly gradient wind, the surface wind – about 330° - 340° – is funnelled down the valley between Dartmoor and Bodmin Moor and tends to persist, particularly if blowing at 15 knots or more, so the north-north-westerly persists down Plymouth Sound while a sea breeze is blowing at Polperro and Bigbury.



Plymouth 1



Plymouth 2

SALCOMBE HARBOUR

Harbour winds & diurnal variation

A harbour wind is almost always blowing offshore, and an offshore wind has three important characteristics:

- It is relatively gusty
- It almost always veers and increases downwind from the shore
- It exhibits a very marked variation between day and night

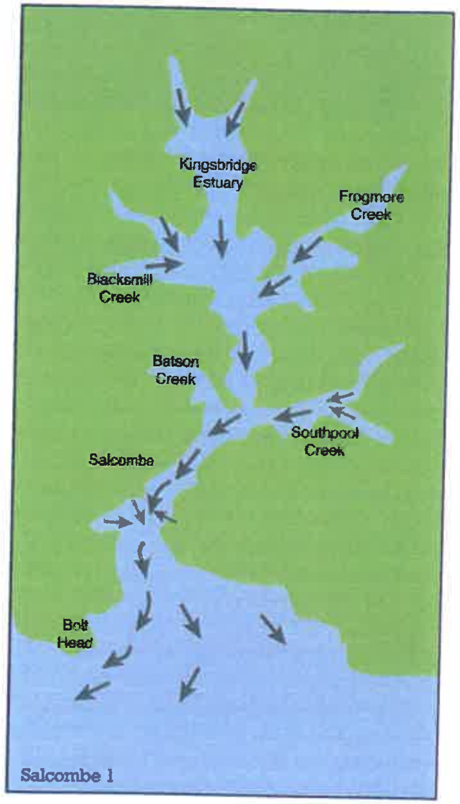
In Salcombe harbour the only onshore direction is a very narrow sector through the harbour entrance. So the wind is usually gusty because of the surrounding hills and valleys. Secondly, one must expect it to be strongest and most veered near the lee shores. Over the open sea the diurnal variation in water temperature is very small so there is little diurnal variation in wind. In harbour, particularly a landlocked harbour like Kingsbridge, although the water temperature does not change, the wind is largely controlled by the land around and it dies in the evening as the land cools. Over the wider areas of water some wind will keep going, but only on stretches of water about three miles wide will the wind strength approach that over the open sea. Later in the night a land breeze may set in.

Land breezes

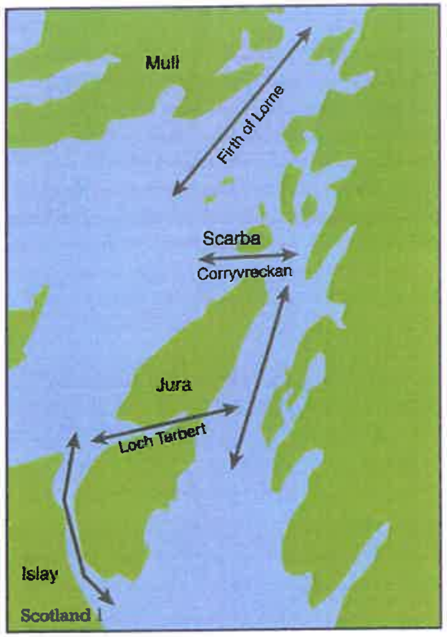
Night land breezes are a feature of many harbours, particularly in hilly areas. Salcombe is no exception. On an otherwise calm night, chiefly when the sky is clear or there is only patchy cloud, land breezes from the direction of Kingsbridge, Frogmore, Southpool, Blacksmill and Batson combine to give several knots of cold wind flowing out through the harbour entrance, fanning out past the Bar and then gradually dying away over the warmer water. (Salcombe 1)

Sea fog

Another feature of Salcombe harbour is the relatively low incidence of sea fog compared with the Channel outside. Again, this is due to the land, particularly the headlands and hills around. Sea fog typically arrives on a south-westerly wind which, to get to Salcombe, has to rise over Bolt Head. As it rises it deposits enough of its moisture to lift the fog 100m or so, and perhaps also allows the occasional burst of sunshine downwind from the harbour. However, there is a very narrow sector through 180° T where the fog can roll through the harbour entrance. A shift of wind of only a degree or two either side of this sector can make a major difference to conditions inside the harbour.



Salcombe 1

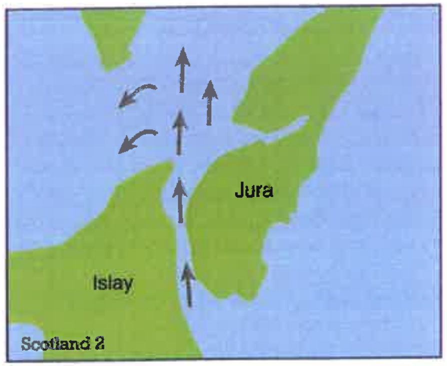


WEST COAST OF SCOTLAND, MULL TO ISLAY

Every day's sailing on the West Coast of Scotland's dramatic and beautiful coast provides a fund of stories about the wind: calm one minute, a squall the next; dropping off the mountain in one place, fanning out from the glen in another.

Most sailors describe the winds as 'tricky' but it is generally agreed that things are not half as bad as they are made out to be and a lot of the variability is related to the shape of mountains and lochs. Common sense is needed when anticipating changes in the wind and weather in this area, which requires two stages of thinking:

- Firstly, to find out where the pressure gradient wind is going, which means looking at the clouds, the latest weather map and applying the weather forecast intelligently.
- Secondly, to think through how the actual and forecast winds will be influenced by



the mountains and islands.

Features of the climate

Winds from all directions can, and most probably will be, experienced when sailing the West Coast of Scotland.

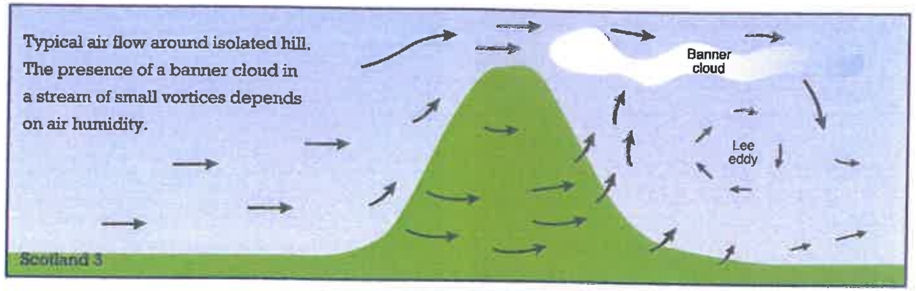
Atlantic depressions often move in from the Atlantic with their centres passing over or close to the Western Isles, giving sequences of southerlies, westerlies and northerlies. Whenever the centre of low pressure is fairly near, the associated fronts and troughs of low pressure are relatively 'active', with spectacular changes between wet and fine weather as they pass, large falls and rises of pressure and big swings in the wind.

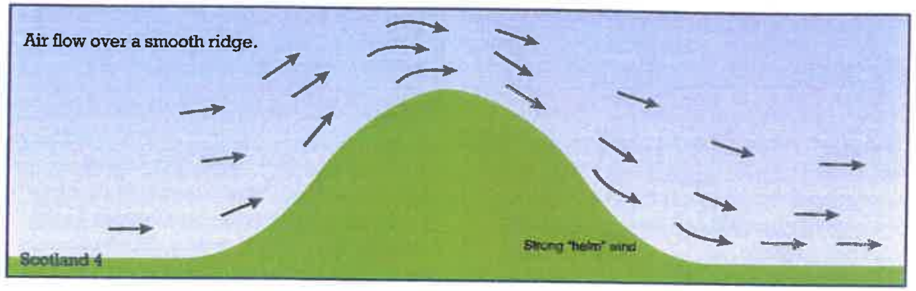
There is a useful relationship between the rate of fall or rise of pressure on a barometer and the expectation of a gale. If the pressure falls more than eight millibars in three hours, a gale is almost certain, whatever the wind was to start with. A rise of eight millibars or more in three hours, after a trough has passed, also heralds a gale.

Because of the Gulf Stream the sea is warm for the latitude, particularly in winter, and the contrast between air and sea temperatures is often great. In cold northerly winds, heating by the sea produces frequent heavy and squally showers. Conversely, fog at deck level is fairly unusual.

Mountains and glens

Funnelling and fanning: Funnelling is the





bending of the wind direction to the contours, that is to the general direction of the firths, lochs and sounds. The obvious through-funnels are along the Sound of Jura, the Firth of Lorne, the Sound of Islay and Corryvreckan. (Scotland 1)

As a rough guide, a wind whose direction is within about 30° of the lie of the sound is bent to blow along the sound. In some cases, where the entrance is wide and the shores steep, the limit may be more like 40°, i.e. comprising an arc of 80°.

Where the sound narrows, the wind increases. A doubling is not uncommon – in the Sound of Islay for instance. Here a venturi effect is sometimes observed, i.e. there is a bank of cloud caused by the drop of pressure immediately downwind from the centre of the constriction.

The amount the wind increases depends also on the stability of the air – that is, whether or not it is inclined to rise. If the air is unstable, typically on a showery day, it rises easily and the increase in strength in the funnel is small – 20-30%. If the air is stable, particularly if there is a temperature inversion (an increase of temperature with height) the air is squeezed both horizontally by the contours and vertically by the inversion, and a doubling of speed – Force 3 up to Force 6, for instance – is not unusual.

Where the funnel ends, the wind gradually returns to its proper direction and speed. Because of the extra backing over land due to friction, the speed on the right-hand shore, looking downwind, will normally be higher than on the opposite shore and this band of stronger wind may extend for some miles downwind. Much depends on the steepness of the coast.

Vertical and horizontal eddies: There are lots of eddies to be experienced around the lochs and sounds, the main reason for the winds being described as fickle. The forecast may say, for instance: 'South-westerly 4 to 5', but reversals must be expected downwind from some of the mountains, ridges and cliffs. They are not random and it is not difficult to guess where they are likely to be. You can see a wind eddy round the corner of a building on a breezy day when there are leaves whirling around.

Eddies develop on the water where a wind suddenly emerges from a sound, the northern tip of Islay, for instance (Scotland 2); downwind from an escarpment; and behind an isolated mountain such as Scarba (Scotland 3). They are all different. Their shape, size and character depend not only on the contours, but also on the vertical and horizontal temperature, wind and humidity profiles of the air, which vary from day to day.

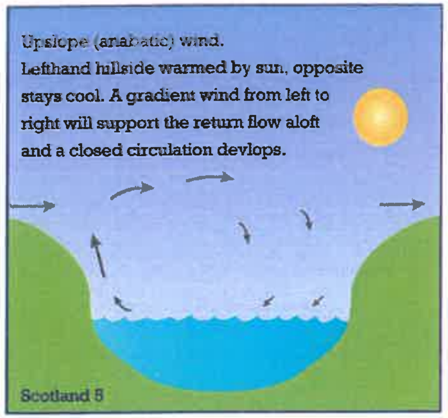
Helm winds: Helm winds, when the wind rushes down the lee slope, are quite a feature of this area (Scotland 4). They are found downwind from a ridge lying across the wind where the slope is just right, the wind Force 4 or more and the air relatively cold, typically in a westerly or north-westerly after a cold front has passed.

So as you reach northwards through the Sound of Jura, you will find not only eddies and a band of stronger wind emerging from Loch Tarbert, but also one or two examples of a stronger wind, double strength perhaps, where the air has piled up against the ridge and is tumbling over the top like water over a weir.

A 'helm cloud' may also be seen and on some occasions can give the best clue to the location of the stronger wind. If the lee slope is too steep an eddy forms, giving a reversal of wind close to the shore and a return to the original direction up to a mile or so off.

Anabatic and katabatic winds: These are particular to mountainous areas. If the land was flat, it would be sea and land breezes. A sea breeze may be a possibility in some of the mainland glens when the gradient wind is offshore, but the most common thermal effect under sunny skies is an upslope or anabatic wind when the gradient wind is light, 15 knots or less.

The reason is not difficult to see. In a hilly area the sunny side of the hill warms while the other side stays cool. So instead of a general warming of the land, giving rise to an overall sea breeze, pockets of warmed air


Upslope (anabatic) wind.
Lefthand hillside warmed by sun, opposite stays cool. A gradient wind from left to right will support the return flow aloft and a closed circulation devlops.

rise up the sunny hillsides (Scotland 5) causing local wind circulations which move as different slopes move into the sun (in the morning, it is the east-facing slopes of Scarba, Jura and Islay; at midday the south-facing slopes, and towards evening it becomes the turn of the west-facing slopes).

The downslope wind (katabatic) is essentially the night land breeze, a consequence of air, cooled near the ground under clear skies, flowing down the slopes, through the glens and out to sea; the steeper the slope and glen, the stronger the wind.

When there is little or no gradient wind, you may experience a katabatic wind during the daytime, coming off cold and snowy slopes of the higher mountains.

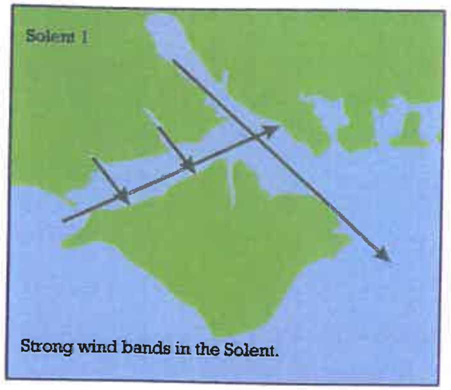
Shelter: The availability of shelter is vital on this rugged coast. For every wind direction there are one or more quiet bays and lochs. In selecting the best anchorage, it is worth considering the possibility of a helm wind. If you are unlucky enough to end up in a strong blow, you may well find that conditions are much quieter a few hundred metres further up or down the coast.

Sailing between Mull & Islay, or for that matter anywhere among the lochs and sounds of the West Coast of Scotland, many of the bends, bands and sudden changes in wind can be anticipated, if only by studying the topography to windward.

THE SOLENT

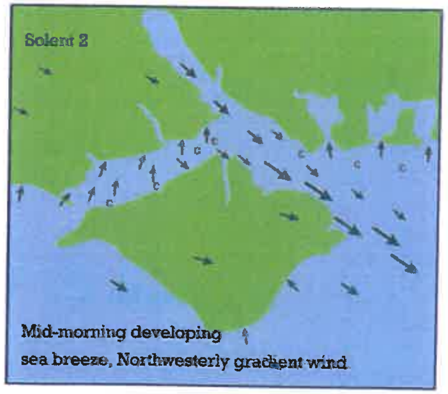
Solent winds have a reputation for being fluky and unpredictable. But the problem is not that we are faced with a mysterious set of circumstances which defy solution, rather a combination of influences on the wind all at the same time. The basic principles which determine wind behaviour near the coast still apply. Everything we have learned in the preceding chapters concerning the behaviour of the wind at a land-sea boundary and the various effects of coasts, headlands, sea breezes and variations in water temperature is relevant to predicting the details of bends, bands and fluctuations in the wind through the Solent. In particular:

- Expect a wind bend wherever the wind is blowing off the land (Figure 3.1): a bend of some 20 to 25 degrees over a distance of about 1 kilometre downwind from the shore in unstable air; more like 3 kilometres in stable air. Note that it is the distance downwind from the land, not the distance from the shore, which is important. If you are beating down the west Solent and the sea wind is 220° you may prefer to stand close in to the Island shore to benefit from a backed and freer wind.
- Expect a band of stronger wind some 1 to 3 kilometres from the shore wherever the wind direction is within 20° of the shoreline and land is to port looking upwind (Figure 3.6). The most notable strong wind band experienced in the Solent is the northwesterly down Southampton Water (Solent 1) which continues down the East Solent, on past Ryde and Bembridge and out into the Channel for a further 20 to 40 kilometres before fading out.
- Expect a zone of lighter wind when the wind direction is within about 20° of the shoreline and the land is to starboard looking upwind (Figure 3.8), except where there is a sea breeze blowing – a very important exception!
- On a bright or sunny day where the

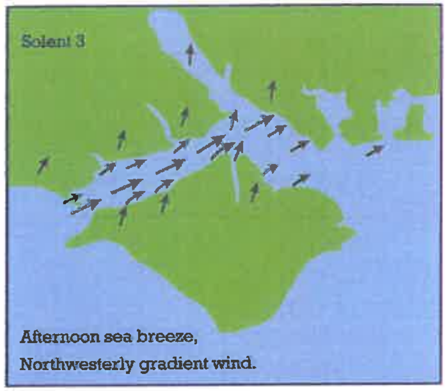


Strong wind bands in the Solent.

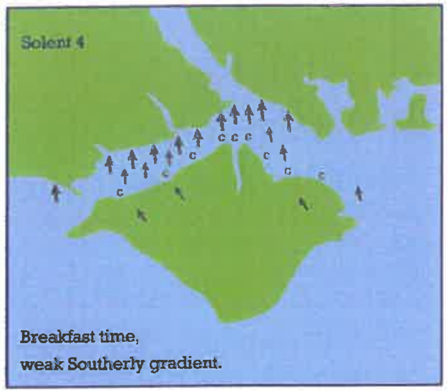
direction of the gradient wind is offshore and the breakfast-time wind is less than about 15 knots, look for a sea breeze. With a northwesterly gradient wind the sea breeze will develop onto the mainland shore in the west Solent and it will typically reach 20 to 25 knots. (Solent 2 & 3). With a southerly gradient a sea breeze will try to get going onto the Island shore, but the island is not big enough to sustain it. (Solent 4 & 5) Typically the new wind will die away after an hour or so. A sequence of attempts will follow, each lasting about the same time so long as there is no change in gradient wind.
- A wind from the south-south-west will be subject to an afternoon thermal



Mid-morning developing sea breeze, Northwesterly gradient wind



Afternoon sea breeze,
Northwesterly gradient wind.



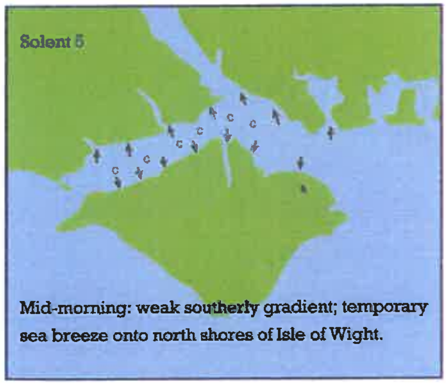
Breakfast time,
weak Southerly gradient.

enhancement of 4 or 5 knots (Figure 9.2) due to the heating of the land mass to the north.
- A wind from a south to southeasterly direction will tend to die in the afternoon.

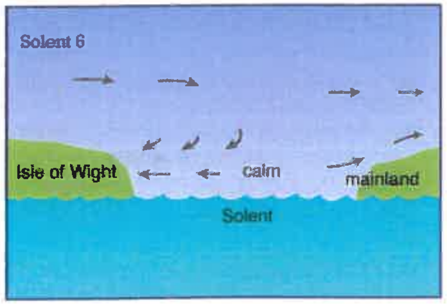
Solent holes

Some holes are very temporary and last less than an hour, some last for a few hours. Solent 2 is typical of winds on the water on a bright or sunny day in mid to late morning with a north-westerly gradient wind as a sea breeze is developing. The calm patches separating the new wind from the old are moving and by the afternoon (Solent 3) have disappeared. Solent 4 and 5 illustrate what happens when the gradient wind is a light southerly – around 5 to 10 knots. The morning is fine. It is calm at breakfast time off Gurnard, but there are a few knots of wind near the mainland shore. As the land warms a weak offshore sea breeze starts onto the north shore of the Island and the calm area moves out into the middle of the Solent. Solent 6 is a cross-section. Because neither the Island land area nor the Solent water area are large enough to support a sea breeze for any length of time, it dies after 20 to 30 minutes and the calm area retreats towards the Island.

The cycle of gentle sea breezes followed by calms is then repeated throughout the day over much of the Solent. So do not put any faith into the occasional puffs of wind onto Egypt Point. Only the wind onto the mainland shore is worth considering.



Mid-morning: weak southerly gradient; temporary sea breeze onto north shores of Isle of Wight.



A particularly interesting feature of the Solent is its ability to offer simultaneously strong winds from totally different directions. The two most striking examples are:

- During the development of a sea breeze with a northwesterly gradient wind. The southwesterly sea breeze builds over the west Solent (Solent 2) while the band of strong northwesterly winds persists down Southampton Water and across to the East Solent. The northwesterly band is reluctant to give way, but eventually the southwesterly breeze breaks through and pushes across to Hill Head and Lee on Solent, leaving the remains of the north-westerly to be mopped up by sea breezes in the East Solent. (Solent 3)
- During the development of a sea breeze in the East Solent when the gradient wind along the coast eastwards from Selsey is in Quadrant 2. In this case the boundary zone between the northeasterly gradient wind and the southwesterly sea breeze – the sea breeze front – tends to stay over the water, and the converging winds produce cumulus and cumulonimbus clouds, sometimes with thunderstorms.

THAMES ESTUARY

Sea breezes and the state of the tide

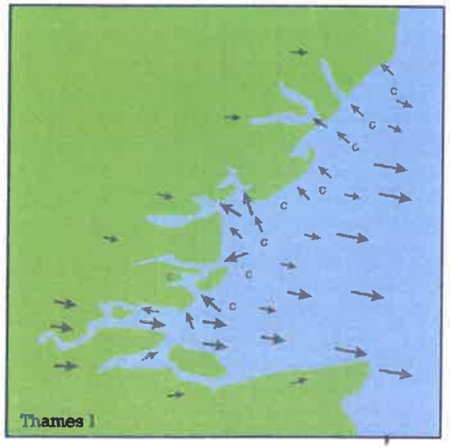
The Thames Estuary provides a variety of interesting wind features. Among the most significant are:

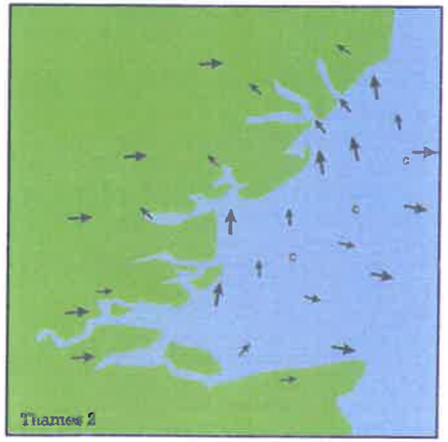
- The high frequency of sea breezes onto the Essex and Suffolk coasts
- The evolution of sea breezes in the estuary funnel
- The differences in local wind between high and low water

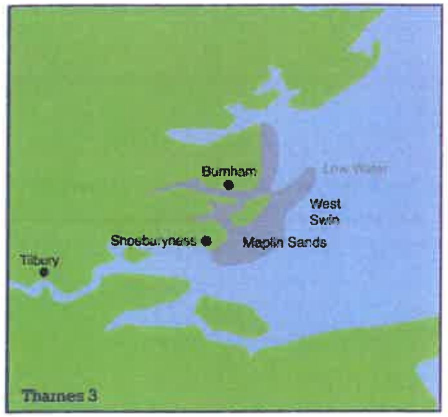
As with all large estuaries, the presence of shores facing in different directions provides clear evidence of the importance of an offshore gradient wind in the generation of a sea breeze. East Anglia experiences a high frequency of onshore sea breezes because of the high frequency of offshore gradient winds from the west.

In the summer half of the year, a morning westerly is typically followed by a mid-morning calm near the shore, then an onshore east or south-easterly (Thames 1) which veers gradually to southerly and increases to somewhere between Force 2 and 5, depending on where you are on the coast (Thames 2).

The development of a sea breeze up the Thames depends critically on the gradient







wind being nearer west than north-west. Thames 1 and 2 are typical of what happens in a north-westerly gradient. When it is near to westerly, a fresh easterly sea breeze penetrates upstream to Westminster and has been seen as far inland as Grafham Water.

Sea breezes and the shape of the estuary

Over the estuary, considerable variations in the strength and direction of the sea breeze are experienced, due to:

- The shape of the estuary funnel, particularly the proximity of the opposite shore. A mature sea breeze will extend up to 30 or 40 miles seawards by mid-afternoon. Where the width of the estuary is less than this, the sea breeze cannot reach its full strength, and the direction is modified as it tries to draw air from further out towards the North Sea (Thames 2).
- Rivers and other inlets. A river lying along the sea breeze direction acts as a funnel carrying the breeze inland. The Colne and Orwell are good examples. The Crouch and Blackwater act as funnels in the early stages of the breeze until the direction veers southerly.

A river across the direction of the sea breeze has very little influence unless it is wide enough to change significantly the average temperature of the land, the warming of which is causing the sea breeze.

Sea breezes and the state of the tide

The influence of the tide on the sea breeze is nowhere better illustrated than off the Maplin Sands. Here, at springs, when sailing in the deep water channel, you are some five miles nearer land at LW than at HW (Thames 3).

One of the important and often useful features of the true sea breeze is that it is noticeably stronger near the shore, because it is supplied by air subsiding over the coastal zone. Therefore, the nearer you are to the land, the more subsided air there is blowing in towards the shore.

Typically, in a fully-developed sea breeze the wind close to the coast will be Force 5 or possibly Force 6, decreasing seawards to Force 2 or 3 at 50 kilometres off. So, sailing through the West Swin on a typical sea breeze day, you are likely to experience something like five knots more wind at low water than at high.

Another important difference between high and low water is the more limited fetch available for the sea breeze at low water. For instance, on the Essex coast from Shoeburynes westwards the estuary is over 30% narrower at low water than at high. The sea breeze is correspondingly lighter during low water.

TORBAY AND WESTERN LYME BAY

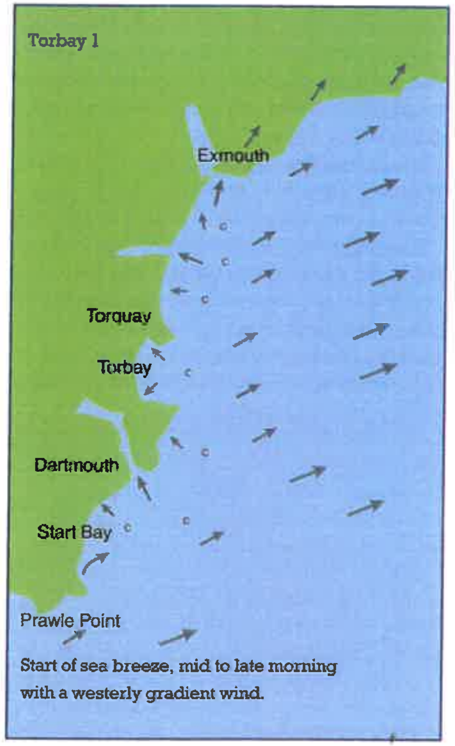
Torbay and the whole western side of Lyme bay, from Dartmouth northwards, have the highest frequency of sea breezes on the south coast of England. This is because this section of coast faces eastwards, so that the prevailing gradient wind – a west to south-westerly – is offshore, the direction necessary to support a sea breeze on any bright or sunny day when the land temperature rises above the sea temperature, and the wind strength is less than about 20 knots.

Typically, through the summer half of the year (and on the warmer winter days), an offshore west to south-west wind dies away near the shore by mid-morning to make way for the developing onshore sea breeze.

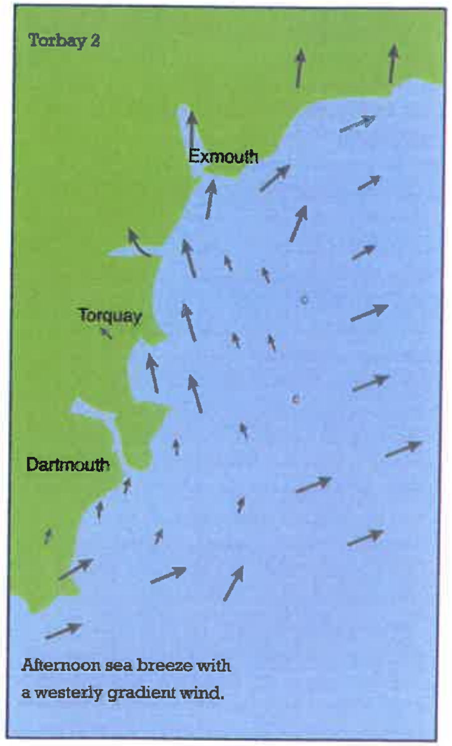
This new breeze starts blowing directly onto all shores – a gentle northerly onto the southern shore of Torbay, for instance, a gentle south-easterly onto its northern shore. It also starts blowing up estuaries and valleys, particularly the rivers Dart and Teign. (Torbay 1)

As times goes by, the sea breeze increases and veers, extends both inland and seawards, and, by early afternoon, settles into a general south to south-easterly direction, ironing out most of the minor bends caused by the shape of the coastline, but still tending to turn into the major river estuaries and valleys. (Torbay 2)

Over Start Bay and around Prawle Point, the sea breeze is relatively feeble when the gradient wind is in the west or south-west, because the amount of land upwind is very limited.



Start of sea breeze, mid to late morning with a westerly gradient wind.



Afternoon sea breeze with a westerly gradient wind.

ATHENS

Gradient 340 ° – 040 °, The Meltemi

The Meltemi is a warm, dry and very gusty NE wind set up between low pressure over Turkey and high pressure over the Balkans. Speeds can range from 8 to 28 knots, often on the same day.

Occasionally the Meltemi can blow all night, but usually there is a general increase between 0900 – 1100, and a slight shift to the right, from 340 ° – 360 ° to 010 ° – 035 °.

Winds in the lee of Piraeus can reach the course from 340 ° – 360 ° on the left and 010 ° – 035 ° on the right throughout the day. (Athens 1)

Sea breezes

Athens has a very unique sea breeze pattern and it is a venue which highlights the necessity to look at not only a local map but a topographic map of the surrounding area.

Sea breezes under a slack gradient

On clear cool nights cooled air piles up behind the mountains to the north of Athens. In the early hours of the morning it finds its way downwards to the Saronic Gulf with a NW'ly direction over the water. As it warms up it turns more onshore towards the city as a westerly, but weakens until it is replaced by a south westerly sea breeze, from 200 ° – 240 °, 3 – 8 knots. This sea breeze tries to shift right, as a normal sea breeze in the northern hemisphere would, and pressure often comes from the right. But these early sea breezes are often very patchy and very light offshore, and complicated by a developing easterly sea breeze blowing on to Egina, the island opposite, so that in the shipping lane the wind is particularly fitful and light.

There is yet another sea breeze to occur in the Saronic Gulf, which comes from the south, 140 ° – 180 °. This is the strongest sea breeze as it is driven by air rising over the

larger land masses to the north compared to the south-westerly sea breeze which is driven by air rising over the city. This latter sea breeze may reach only 8 – 12 knots in the summer and up to 14 – 18 knots in the Spring and Autumn. Stronger winds are to be found near Piraeus, and lighter winds with a change of wind direction along the eastern shores of the bay. Step changes in sea breeze direction and speed are typical on most days as successive mountain slopes are exposed to the sun and then move into shade.

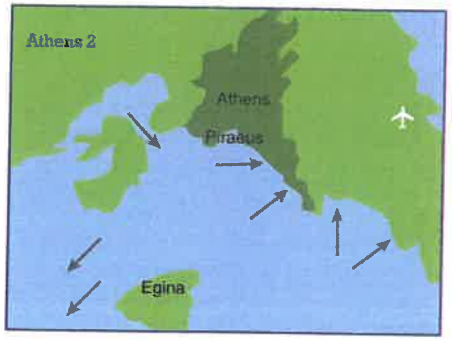
Sea breezes rarely occur under moderate to strong Meltemi conditions, despite its offshore component.

When the weather is stiflingly hot and stable the sea breeze really struggles to break through the inversion layers and the resulting breeze is exceptionally light and unstable, making sailing conditions tricky as there is no pattern. The weakest winds occur when the inversion layer is below the tops of the higher mountains and a general sea breeze cannot develop, only a handful of small sea breeze circulations up the various valleys, some more effective than others in drawing air off the water.

Gradient wind 300 ° - 360 °

Strong SSE sea breeze 12 – 17 knots, when the atmosphere is more unstable earlier and later in the year.

A N – NW gradient can also drive an easterly sea breeze on the coast to the east of



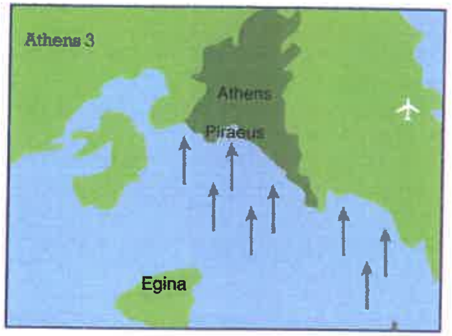
the International Airport which can reach more than 15 knots as there is more land to drive it. It can make its presence felt after 1630 on the Saronic Gulf just on the courses closest to the Olympic Sailing Centre.

Gradient wind 040 ° – 100 °

A gusty and shifty wind as it is blowing over rough ground. When sailing off Piraeus winds are channelled down the Athens City valley, and gains can often be made on the right closer to shore. Further south the wind becomes less predictable as it is affected greatly by hills to the south of Athens.

Gradient wind 250 ° – 300 °

A reasonable fetch means waters can be quite choppy from this fairly steady direction. Wind tends to be fairly constant across the course, unless sailing close to the Piraeus shore, where streamlines are divergent and lighter winds may be found on the right.



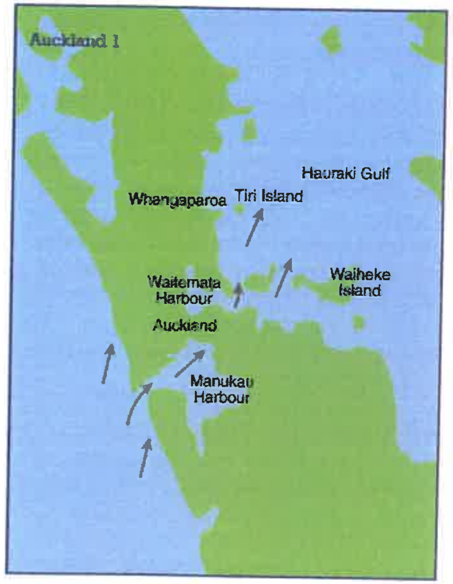
AUCKLAND

Auckland Harbour and the Hauraki Gulf present very complicated coastlines and numerous headlands and islands around which one must look for the associated wind features. Four seasons in one day is a common local saying, suggesting, quite correctly, that the weather in Auckland can change dramatically and often.

Gradient wind 180 ° – 260 °

South-westerly winds can be cold and gusty at all times of the year. SSW'ly cold winds from the Southern Ocean cannot penetrate the mountainous barriers of South Island so flow through the Cook Straight or northward, to the next channel which is Manukau Heads. Channelling through Manukau Heads and down the Waitemata Harbour can cause winds to be five to ten knots more than the average surface wind speed. Frequent showers are associated with a south westerly wind, often giving squally conditions and wind ranges of 5 to 25 knots.

When sailing on the Hauraki Gulf look for



a lift on port tack when approaching the East Coast bays shoreline.

Gradient wind 260 ° – 020 °

i) North westerly gradient, <15 – 20 knots, warm and relatively clear skies.

A light NE sea breeze forms in the Hauraki Gulf & a stronger SW sea breeze forms on the west coast which has a greater supply of rising warm air over the land to the south of the city. The NE only has a very small land mass to supply its rising warm air and so reaches a maximum speed of only 4 – 8 knots. The initial direction is from due east which soon backs towards the north east, eventually ending up blowing from 005 – 020. The stronger 10 – 16 knot south westerly sea breeze often reaches the Harbour Bridge and occasionally, but briefly, blows onto western areas of the Hauraki Gulf but it does not reach as far north as Whangaparoa.

ii) A north westerly gradient above 15 to 20 knots, or under cloudy skies will tend to channel out of the river near to Gulf Harbour, and through the Tiri Passage. The winds are likely to be shifty inside the harbour.

Gradient wind 020 ° – 100 °

Often created by sub-tropical lows and active warm fronts moving down from the north, expect a large swell and rough waves in the Gulf. Due easterly winds are greatly affected by the high Coromandel mountains, creating a wind line marking strong winds to the north around Tiri Island and lighter winds to the south. The Harbour is relatively sheltered from the north east to east.

Gradient wind 100 ° – 180 °

There are many topographic features to affect a south easterly wind such as head-lands, islands and channels. Look for the features described in Chapter 6 such as zones of convergence and divergence.

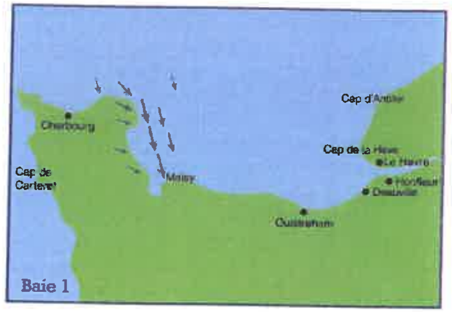
BAIE DE LA SEINE

This large bay from Pte de Barfleur to Cap d'Antifer is some 100 kilometres across, and you might think that because of its size and the flatness of much of the coast the winds would be relatively steady and uninteresting. But in fact the bay provides a variety of interesting wind patterns, so much so that sailors meeting in the bar at Ouistreham having arrived from Cherbourg and Le Havre often have very different stories to tell. Sometimes light and fluky winds for one and a rock steady 10 knots or more for another. What is more, changes in gradient wind direction of only a few degrees from one day to the next may lead to significantly different sailing winds, especially in the afternoon. We look first at the western side of the Bay where both Pointe de Barfleur and the Baie du Grand Vey have attracted the description 'windy corner'.

Windy corners

Pointe de Barfleur is an obvious candidate for the label 'windy', and it is easy to see why. For all directions from about 290 ° to 340 ° degrees the wind piles up against the land to the west of the point and sluices around it, continuing with an extra 2 or 3 knots for some distance downwind. The biggest increase is found when the direction is near 340 degrees. Then there is convergence of the land and sea winds along the stretch of coast south of the point creating a strong wind band which extends downwind (Baie 1), skirting the Isles de Marcouf and hitting the coast near Pointe de Maisy with 3 to 5 knots of extra blow.

At first sight the Baie du Grand Vey should provide good shelter for all winds coming off the land, from points between about west and southwest. But it turns out to be surprisingly windy. What happens is that the wind hitting the west side of the Cherbourg peninsular finds that the easiest route across the land is the neck of low ground to the southwest of the Baie du Grand Vey. This funneling effect



gives an extra knot or two over the Bay. In addition, when the wind direction is near 280 degrees over the water it is enhanced by two other factors (Baie 2):

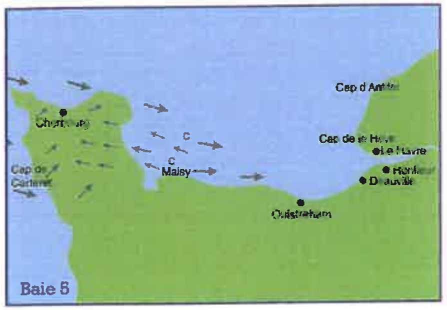
- The shape of the coast south of Cap de Carteret
- Convergence of the land and sea winds over the Bay; the wind veering over the water as it leaves the land on the west side of the bay meeting the more backed wind on the south side of the Bay.

So where you might expect shelter you find a blow; an extra Beaufort Force in the situation of Baie 2. However, much of Utah Beach just to the north remains relatively sheltered.

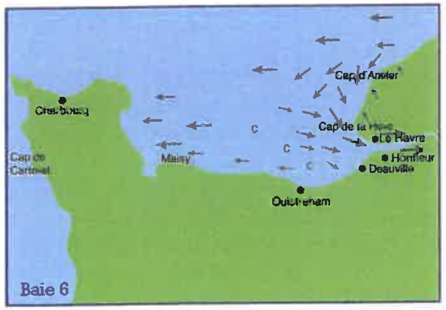
Baie du Grand Vey to Deauville

This stretch of coast, being relatively flat and featureless provides a good illustration of how, when the wind is blowing nearly parallel to the coast, the difference between the friction over the water and over the land causes significant changes in wind strength. It also highlights the importance of the angle of the wind to the shoreline, which must be within about 20 degrees for the changes to be noticeable. Where the coast bends through about 40 degrees between Ouistreham and Deauville there is no continuity of strong or light wind bands. In summary, along the stretch of coast from Grand Vey to Ouistreham expect the following:

- When the wind direction is 280 to 290 degrees, convergence of land and sea winds, and a stronger wind within 3 to 4 km of the shore; i.e. if you want wind stand in, if you don't stand off. On a bright or sunny afternoon the decrease in wind near the shore is greater because of a fall in pressure over the land due to heating.
- When the wind direction is 070 to 080 degrees, divergence of land and sea winds leading to a relatively lighter wind



Baie 5



Baie 6

near the shore; i.e. if you want wind stand off, if you don't stand in. However, on a bright or sunny afternoon the decrease in wind near the shore is cancelled out by thermal effects.

Cap d'Antifer to Honfleur

The influence of Cap d'Antifer is important mainly for winds blowing out of the Bay. With a south-south-westerly, convergence of land and sea winds gives a strong wind band along the coast northwards from Cap de la Heve (Baie 3). This continues downwind for 30 km or more from Cap d'Antifer and out into the Channel. North-easterlies on the other hand are subject to coastal divergence and are relatively light along this coast except in a sea breeze situation.

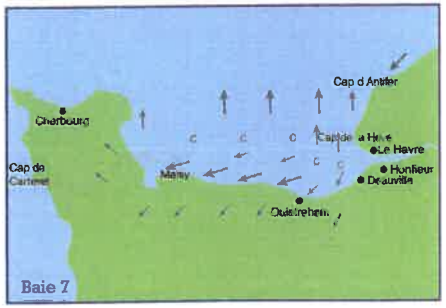
In the approaches to Le Havre west-south-westerly and easterly winds are relatively strong (Baie 4); west-south-westerlies because of convergence of land and sea winds upwind along the coast past Deauville and Honfleur; easterlies simply because the valley is the easiest route for the wind to take. When approaching Le Havre in either a west-south-westerly or an easterly the extra wind will make the tide a particularly important factor if you want to avoid a very uncomfortable big chop.

Sea breezes

It is in sea breeze situations, on a bright or sunny day, that the biggest variations in wind are found between one side of the Bay and the other; in some ways not unlike Torbay.

And there are big differences in the way the sea breeze develops depending on whether the initial wind is westerly, easterly or southerly. The three are worth looking at separately.

- In a westerly the eastern side of the Bay enjoys a steady wind while a sea breeze develops onto the Cherbourg peninsula. This starts as a light onshore easterly, slowly increasing and veering towards south-south-easterly. But then there is a problem. This peninsular is not wide enough. After two to three hours the sea breeze penetrating inland reaches cool air blowing in from the west-facing shore. Thus the driving force of the sea breeze - air heated over the land, rising and moving out seawards on the gradient wind aloft - is cut off, and the sea breeze dies. The westerly then returns, across the land and out into the Bay; it starts to warm again over the land and the whole process is repeated. Baie 5 illustrates the stage of



Baie 7

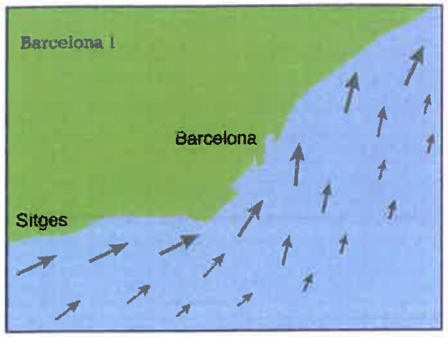
maximum development. Day-to-day details vary according to the strength and direction of the gradient wind.

- When the gradient wind is easterly it is the turn of the western side of the Bay to experience the steady wind and the eastern side the sea breeze. This develops from mid-morning onwards onto the coast from Honfleur northwards, starting as a light westerly, increasing and veering towards the NNW and drawing air in around Cap d'Antifer (Baie 6). There is no limit to the inland penetration of the breeze, so it develops unhindered and is likely to reach Force 4 or 5, extending seawards well into the Bay. Near the Seine estuary the shape of the coast and the opportunity to run inland up the valley keep the direction nearer to west.

- In a southerly the sea breeze develops onto the coast from Maisy to Houlgate and veers towards the east. It is immediately apparent that while this development can progress unhindered on the western side of the Bay, typically reaching Force 4 or 5, it is severely restricted on the other side, where light and variable winds result. Baie 7 illustrates what happens. Again the details vary depending on the strength and precise direction of the gradient wind.

Land breezes

Night land breezes are for the most part feeble, much of the coast being fairly flat. As always, the best breezes are found at the mouth of the most significant valleys, seawards from Deauville, Houlgate and Honfleur. In the approaches to Le Havre yacht harbour the breeze is a knot or two stronger at low water than at high, when there is much less water upwind to warm it up.



BARCELONA

(see also Chapter 9 page 42)

Winds at Barcelona in the summer six months of the year follow a pattern typical of places:

- On a relatively straight coast
- Where an adjacent large land mass becomes hot in the afternoon (but not in the tropics)
- Where gradient winds are normally light.

Morning gradient less than 2 or 3 knots – any direction

The morning starts calm and the air aloft is just drifting around. Heating of the land causes the pressure to fall overland and an along-shore gradient sets in by midday. Typical features of the wind on the water are as follows:

- It starts before mid-morning as a pure sea breeze at right angles to the coast (from 140 degrees at Barcelona), which swings to the right and increases for a while.
- The thermally -produced gradient parallel to the coast then takes over, pulling the direction round to 15 degrees from the shoreline by early afternoon (195 degrees at Barcelona), with a slight bend inshore near to the shore.
- At the same time the speed increases to around 10 knots over a coastal zone about 5 to 8 kilometres wide.
- Swings in direction between 195 and 220 degrees arise from interactions with the wind produced beyond a bend in the coast upwind.

Gradient wind in Quadrant 3

It often happens that the morning starts with a remnant of the southerly wind of the previous day, in which case the final direction and the swings are the same as above but the speed is 5 knots or so higher. South-easterly winds also swing right but not so far, and with only 2 or 3 knots increase in speed.

Westerly gradient – Quadrant 1

A Quadrant 1 gradient wind is relatively infrequent and is most likely following the passage of a cold front, usually a weak front and barely recognizable as a front except for a change to much clearer air. A sea breeze sets in early, extends seawards, swings to about 210 degrees and increases to 20 to 25 knots near the shore. The direction fluctuates between 210 and 225 degrees because of interaction with the breeze around the corner upwind. (Barcelona 1)

East to northeast gradient – Quadrant 4

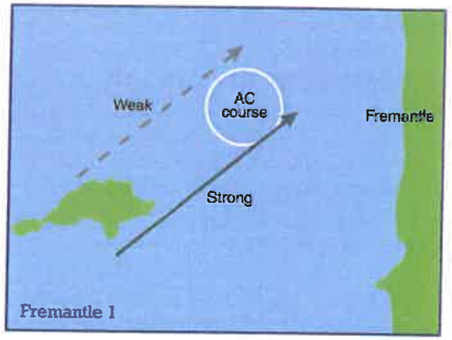
A morning wind over the water between about 020 and 100 degrees is usually killed by the opposing thermal vector. But if it is less than about 5 or 6 knots it ends up (either pulled round or stopped and started again) at about 160 to 180 degrees with probably a small increase in speed.

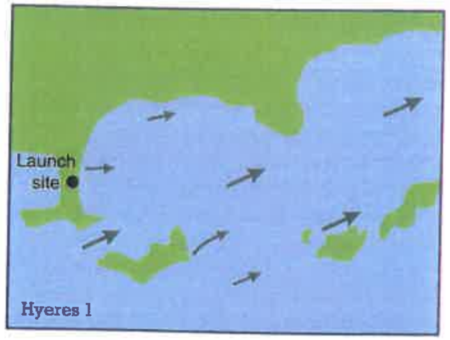
Northerly gradient – Quadrant 2

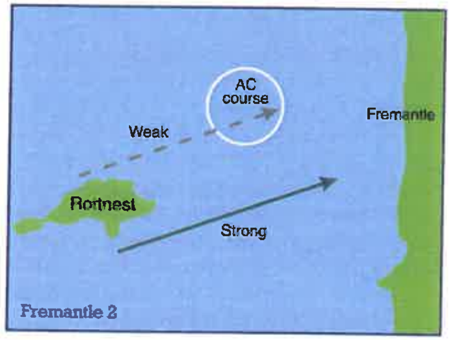
This is rarely if ever found in summer at Barcelona, because of the Pyrenees.

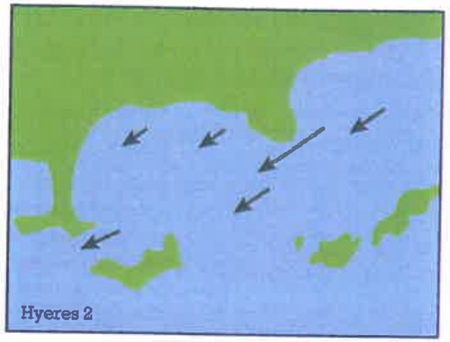
FREMANTLE

Fremantle is renowned for its 'Fremantle Doctor' which, as local weather lore would have it, blows on the great majority of days. In our experience 'always' in local weather lore is normally about 45% of occasions. This is certainly so in the case of Fremantle









which for the period of the America's Cup racing was well equipped with weather buoys just offshore. The reason for the large discrepancy is that local lore did not discriminate between the 45% of occasions which were genuine sea breezes blowing at 25 or so knots, and other occasions – some 25% – of southwesterlies which did not exceed 15 knots and were merely the product of a thermally-enhanced gradient. It was crucially important in the AC racing to make this discrimination both in regard to sail selection and tactics on the water.

A second feature of racing at Fremantle is the presence of Rottnest Island, usually almost directly upwind. (Fremantle 1 & 2). Chapters 3 and 6 (and Fremantle 1 & 2) show how important it is to identify the exact positions of the bands of stronger and lighter wind downwind of an island, in relation to both the wind direction and the course area.

HYERES

Gradient wind 280° – 020°

i) gradient less than about 20 knots, sunny over land, little cloud. Initial sea breeze development onto all shores including the island to the south, will eventually be replaced by a south westerly sea breeze (220° – 240°) reaching up to 15 – 18 knots, which moves in from the west. Orientation is vital as the launch site faces east, and it is the shores to the north where the strongest winds are to be found. (Hyeres 1)

ii) Gradient over 20 knots, or an overcast and cloudy day, expect the usual patterns of an offshore breeze. High mountains to the north create gusty winds which will attempt to channel out of the valleys.

iii) It is rare to sail in a mistral wind which often reaches speeds in excess of 30 knots (see Chapter 13 for further explanation).

Gradient wind 030 ° - 080 °

A light, < 15 knot, NE gradient wind encourages a weak south to south westerly sea breeze into the Hyeres valley, but the surface NE'ly continues to blow along the Cote D'Azur and then out over eastern race courses. Calm or very variable winds are common where the sea breeze and the gradient wind meet. (Hyeres 2)

Stronger north-easterly winds (Hyeres 2) create an area of acceleration under the cliffs outside the Bay to the north east and east, and a lighter area just under the cliffs inside the bay.

Gradient wind 090 ° - 270 °

Easterly winds are relatively steady in speed and direction with seas building quickly. Look out for the effect of the islands when they are upwind. Winds can be channelled between the islands, particularly south westerly winds between Hyeres peninsular and Ille de Porquerolles.

KIEL

Gradient wind 010 ° to 100 °

Wind over water in range 350 to 080 degrees. If Als or other land is upwind (surface wind) look for a band of stronger wind trailing downwind over the course area; though if wind speed less than 10 knots expect breakaway eddies instead. The effect of afternoon heating of the land is likely to be noticeable only if the surface wind is light and between about 350 and 020 degrees.

Gradient wind 100 ° to 160 °

Morning wind on water east to south-easterly. Afternoon wind will be enhanced by 5 to 10 knots due to heating of the land and the direction will change (back or veer) to become more parallel to the coast – see page 40. Expect a bend towards the coast , particularly on the right hand side of the beat.

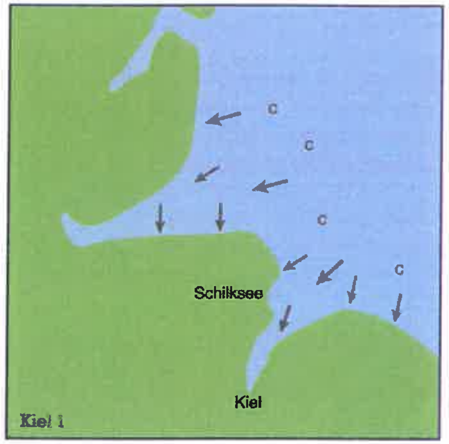
Gradient wind 160 ° to 250 °

(i) If gradient less than about 20 knots, sunny or bright over land - arrows in Kiel 1 indicate initial stages of sea breeze development. However, details depend on the angle of the initial (offshore) wind to the coast, e.g. when the gradient is in the southwest the sea breeze will start close to the coast near the course area and spread steadily seawards. Arrows in Kiel 2 show the likely pattern of the afternoon sea breeze. It is always strongest inshore.

(ii) Gradient over 20 knots and sunny, or light gradient and cloudy. Expect offshore wind to continue, but with swings and holes due to occasional attempts at sea breeze.

Gradient wind 260 ° to 290 °

Morning wind on water between south-west and west. Sea breeze generation will be preferentially on to the shores to the south-west and north-west of the area.

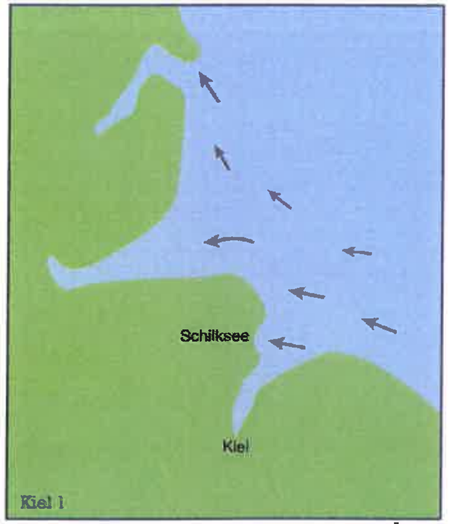


Gradient wind 290 ° to 010 °

Expect gusts and swings in the wind due to the influence of land and fjords. Look for bands of stronger wind downwind of coastal features lying along the wind.

If gradient is between 290 and 310 degrees look for sea breeze influences:

- On landward (SW) side of course
- On NW side of course as sea breeze onto land north of Eckernfoerde extends seawards.



LAKE GARDA

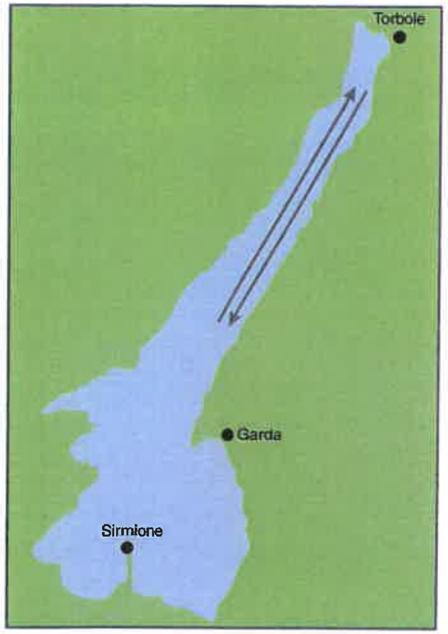
Lake Garda provides a fairly extreme example of katabatic and anabatic winds. Air warmed on whichever slopes face the sun rises readily during the day; air cooled on all the slopes at night drains downwards to the lake.

Peler (northerly wind)

Cooled air in the mountains to the north flows southward during the night and early hours of the morning. The locally named Peler or Vento winds can reach Force 5 or 6 gusting Force 7, but soon lose strength as the sun comes up and are often gone by 9 or 10am.

Ora (southerly wind)

Hot air rising over the mountains to the north of Lake Garda causes a southerly wind to flow up the lake, sometimes reaching Force 4 or 5 at the northern end, but often only Force 1 or 2 in the southern end of the lake where it widens.



The steep-sided cliffs cause zones of convergence beneath them often creating a biased racecourse. There are headlands as well as cliffs, and the wind pattern is greatly affected by them. Look for lifts into and away from those headlands.

Many mornings may be spent waiting for the wind to fill in from the south. Cloud cover and gradient wind direction affects how early or late the Ora can start. The more cloud cover the less heating so the later the Ora will develop, perhaps not at all.

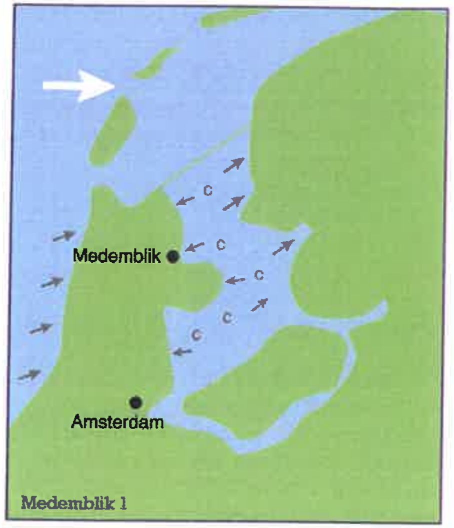
Any gradient wind will be forced either to blow over the mountains or along the lake. If a strong gradient wind is blowing at 90° to the N/S axis of the lake, there is likely to be very little wind on the surface. Occasionally large squalls will fall off the cliffs with a direction close to the axis of the lake. Gradient winds over the mountains will be channelled along the valley.

Even in the height of summer, very cold waters from the deep alpine lake can be brought to the surface after a period of strong winds, which are common from the north-west. Wetsuits are required all the year round.

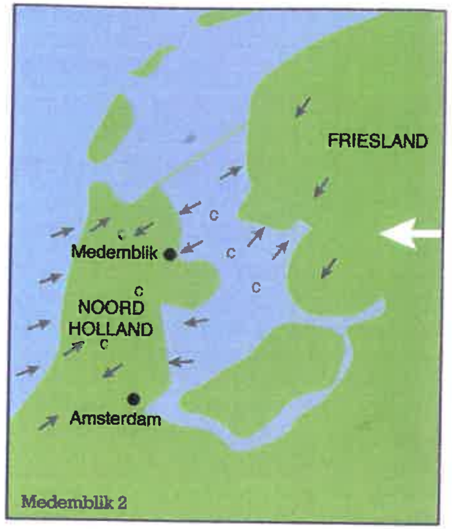
MEDEMBLIK Ijsselmeer

The major characteristic of the Ijsselmeer is the flatness of the whole area and the minimal contrast between the water surface and the surrounding 'land', which is mostly short grass, mud, or shallow water. The surface wind is backed from the gradient wind by a mere 10-15°, as opposed to 30-40° over a typically rough hinterland. In consequence:

- The veer in an offshore wind is noticeably less than normal as it moves off the land, and is complete within the first 500-1500 m downwind from the shore.
- Coastal convergence and coastal divergence are significantly less pronounced than normal, but they are present. For instance, with a wind almost due northerly expect a band of stronger wind on the port side of the racing area north of Medemblik.
- Being shallow and non-tidal the Ijsselmeer is relatively warm from May through to October, and subject to much larger variations in temperature than north of the dyke.
- After several sunny days or in strong



Medemblik 1



Medemblik 2

winds, areas of warmer and cooler water are encountered, moving around the Ijsselmeer, large enough to influence the surface wind significantly.
- Being shallow, the water is often choppy.

Sea breezes

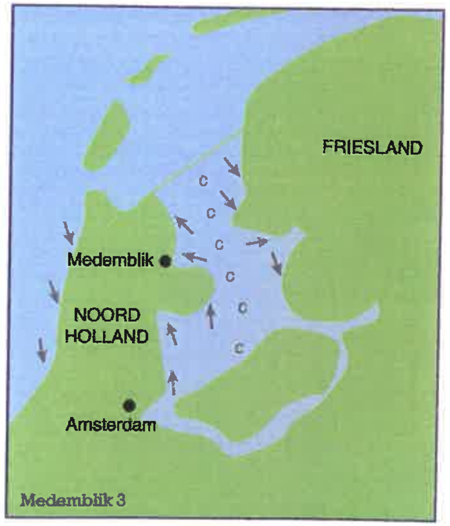
Sea breezes are an important feature of the afternoon winds in the summer half of the year. Given a gradient wind less than 20 knots and a bright or sunny day their incidence may be summarised as follows:

Gradient wind direction westerly (SW through to NW)

A sea breeze develops onto the sailing centre shore. Figure Medemblik 1 shows its start. However with only a limited depth of land upwind, the breeze is doomed and dies after a couple of hours having reached the west-facing shore of Noord Holland. It then starts again and the cycle is repeated.

Gradient wind direction easterly (NE through to SE)

This is a Quadrant 1 or 2 gradient and supports the sea breeze onto the west-facing coasts of Noord Holland and Friesland. The wind starts onshore onto the sailing centre shore and much of the racing area (Medemblik 2), but as soon as the westerly sea breeze develops onto the western coasts of Noord Holland and Friesland the latter becomes dominant with a north-westerly sea breeze becoming established over the whole area: a genuine



Medemblik 3

sea breeze despite blowing offshore at Medemblik.

Slack gradient

Three sea breezes try to develop: westerlies onto the two west facing coasts, and an easterly onto the sailing centre shore, with a calm patch in the centre of the Ijsselmeer (Medemblik 3). None of the breezes reaches above 6 knots. The breeze onto the eastern shores has more land mass at its disposal so it extends westwards towards the race courses at the expense of the sea breeze further west, preceded by calm patches. It is not unusual to find two different wind directions at the top and bottom of an eastern course.

SE – SW gradient

A SE – SW'ly gradient gives a N veering NE sea breeze on the shore to the north east of the Ijsselmeer which may move in by evening. In the morning the SW gradient may drive a weak easterly onto the sailing centre shore, but the south westerly gradient generally seems to hold as there is not enough heated land mass to the west to supply the breeze at Medemblik.

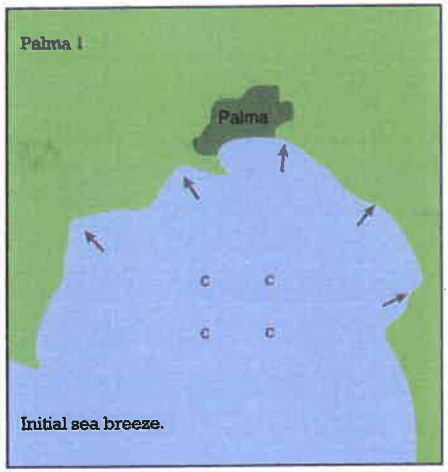
PALMA

The Bay of Palma is protected from the west clockwise to the south east. Winds in the bay when blowing offshore are affected by local topography and by frictional effects described in previous chapters.

Although Palma can experience winds from all directions, one of the most frequent is the south westerly sea breeze. A sea breeze forms under a slack gradient or an offshore gradient which is less than 15 knots.

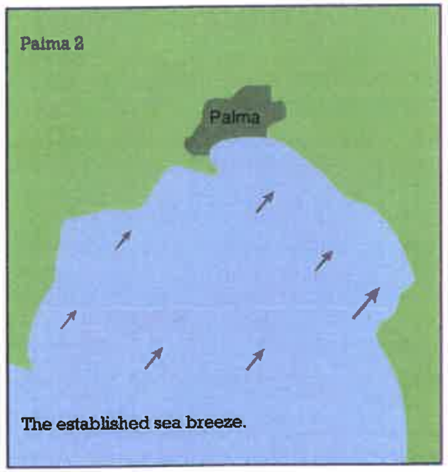
Initial development involves onshore winds blowing onto all sides of the bay, with a large calm patch in the middle. (Palma 1) Eventually the south westerly sea breeze invades the whole bay, veering from the SSW to the SW or WSW within the first few hours.

Once fully formed and stable, there are marked differences across the bay. A convergence zone exists under the cliffs to the south, often making the left the favoured side. Courses in the middle of the bay experience fairly even winds. Northern courses feel the effects of Cap de Cala Figuera, the headland to the west of Magalluf, with less wind on the right of the course.



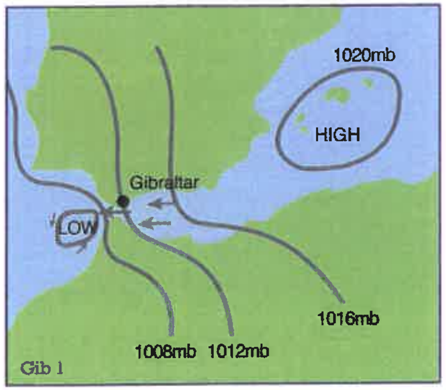
Palma 1

Initial sea breeze.

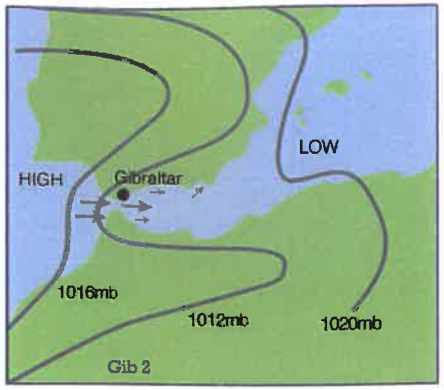


Palma 2

The established sea breeze.



Gib 1



Gib 2

STRAIT OF GIBRALTAR

The Strait of Gibraltar is the only sea level gap for hundreds of miles, between the Spanish Sierras to the north and the Atlas Mountains to the south. So it is not surprising that for much of the time air is pouring through the gap, either eastward or westward.

Nor is it surprising that local names are attached: the wind from the east is the Levanter; the wind from the west, the Vendaval. On average, about 80 per cent of winds are either easterlies or westerlies, and long spells of either are not unusual. One of the longest easterly spells ever experienced at Gibraltar lasted 30 days in November / December 1953.

Typical weather maps

It is not difficult to envisage the sort of weather map which might be associated with either a Levanter or a Vendaval: high pressure over Spain and low pressure over North Africa for an easterly Levanter in the Strait; pressure low over Spain and high over North Africa for a westerly Vendaval.

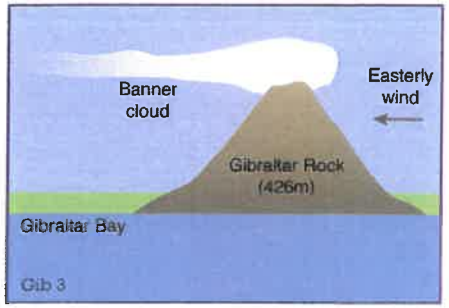
Some bending of the wind through the Strait must also be expected, the sort you look for when sailing between mountains, so that any direction between north-west and south-west becomes a westerly, and any direction between south-east and north-east an easterly.

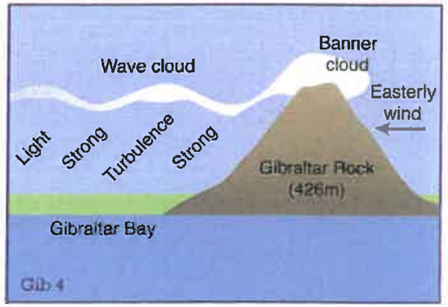
As for the increase in speed, an extra ten knots is typical, and it may be more. For instance, sailing round from Marbella in a westerly, you may be enjoying a Force 1-3 on the Spanish coast; expect it to increase suddenly to Force 5-6 around Europa Point.

Winds across isobars

Unique to the Strait of Gibraltar however, are the weather maps shown in Gib 1 & 2, when the wind blows directly across the isobars, from high to low pressure. This happens quite often when the air is stable and an area of high pressure develops to the east or to the west of the Strait. The air out of the high sweeps through the narrows, westwards or eastwards. It emerges as a band of strong wind which, rather than fanning out, forms standing eddies of varying sizes. Sometimes an eddy is large enough to be mapped by the isobars – a small centre of low pressure (Gib 1). Smaller eddies can often be seen from aircraft.

So, when running though the Strait be prepared for a major change in wind, especially in the middle, from a relatively smooth and steady blow as you approach the narrows to wildly variable conditions as you leave. The details of these eddies, particularly the smaller ones, cannot be adequately described in any forecast, but on the assumption that they all circulate





anticlockwise, it is often possible to make sense of what is happening as you sail through them.

The waves can be a problem. They are often confused because of the eddies in both the wind and the current, and steep rolling breakers are often encountered.

The Levanter banner cloud

A striking feature of the Rock of Gibraltar in Levanter conditions is its banner cloud (Gib 3), often the only cloud for miles around. This is visible from a considerable distance seaward, and its appearance as you approach from the east is a useful indicator of the strength of the easterly in the Strait.

In a weak Levanter, only the top 30 m or so of the Rock is obscured and the banner is short. In a strong Levanter, the cloud covers most of the Rock and the banner extends several kilometres downwind.

Gibraltar Bay

The banner cloud is also indicative of conditions in Gibraltar Bay, to the west of the Rock. Sometimes instead of a continuous banner, the cloud breaks into a series of smooth-looking rolls. These indicate wave motion downwind from the Rock with zones of strong winds on the water, separated by areas of either turbulence or very little wind (Gib 4).

Often there are three rolls over the Bay. Under the first one, about a kilometre downwind from the Rock, the turbulence can be severe. Under the second and third, there may be very little wind, the strength dropping from 20 knots or so to nil within a short distance. The positions of the rolls and the associated wind features in the Bay remain stationary for hours – in fact, for as long as the wind aloft and the stability of the air remain unchanged. In summer, the Levanter is very humid with poor visibility, little variation in temperature between day and night and very heavy dews. Onshore, much of the town of Gibraltar is enveloped in cloud and a general air of gloom sets in after a few days.

The Vendaval

The Vendaval typically arrives following the passage of a cold front, with the gradient wind veering to the north-west. The air is much fresher than in a normal Levanter and often fairly unstable, so that instead of a banner cloud, the Rock causes puffy cumulus clouds to form, which drift away downwind. The fact that these clouds are not stationary, but blowing away with the wind, means that you should not expect to find the surface effects of standing waves downwind, ie stationary zones of strong wind separated by light winds and turbulence.

If, however, the high to the west moves in fairly close, as in Gib 2, the air is likely to be stable enough to give standing waves. The absence of a cloud on the Rock means only that the air is dry.

Waterspouts

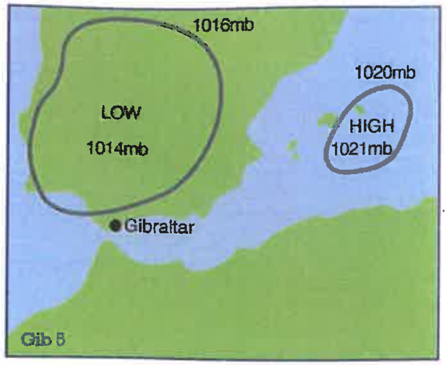
Waterspouts are probably not as frequent in the Strait as legend would have it. They are most likely to form when the air is unstable and the sea relatively warm, typically in thundery conditions or following the passage of an Atlantic cold front, for instance.

They are most frequent in the Strait in the early autumn when the sea temperature is at its highest, at about 23 °C. The convergence of land and sea winds can help to trigger them: near the North African coast in a westerly for instance or near the Spanish coast in an easterly. They have also been observed just west of the Strait in an unstable easterly, probably in association with wind eddies.

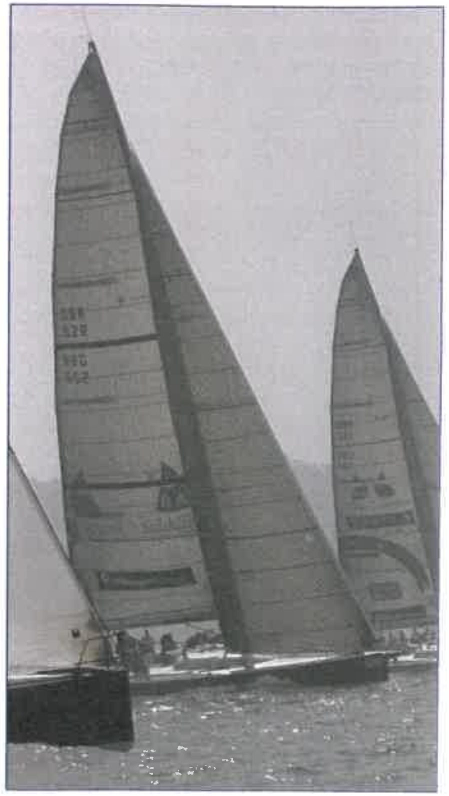
Afternoon 'sea breezes'

The best-known afternoon wind in the area is the 'Bay of Gibraltar Sea Breeze'. However if you are going to race in it, and race to win, you will have to forget that it is called a sea breeze. It is in fact a thermally enhanced wind as defined in Chapter 9. It occurs only when the gradient wind is in the west and is due to heating of the Spanish mainland. A westerly wind means relatively low pressure over Spain. Gib 5 is a typical summer weather map for midnight. Heating of the land mass during the day causes the pressure overland to fall by 4 to 6 millibars, making the low that much lower. This increases the pressure gradient near the coast, equivalent to adding an extra isobar roughly parallel to it. The consequently stronger south-westerly gradient along the Spanish coast to the north-east of Gibraltar draws an extra five to ten knots of wind through Gibraltar Bay in the afternoon. This is stronger than most thermally enhanced winds but stronger simply because of the sluicing effect round the rock.

For the same reason an extra north-westerly component of wind is experienced in the afternoon off Cape Trafalgar. The point to bear in mind when racing is that you must not bank on the wind being strongest close to the coast as is always the case in a true sea breeze.



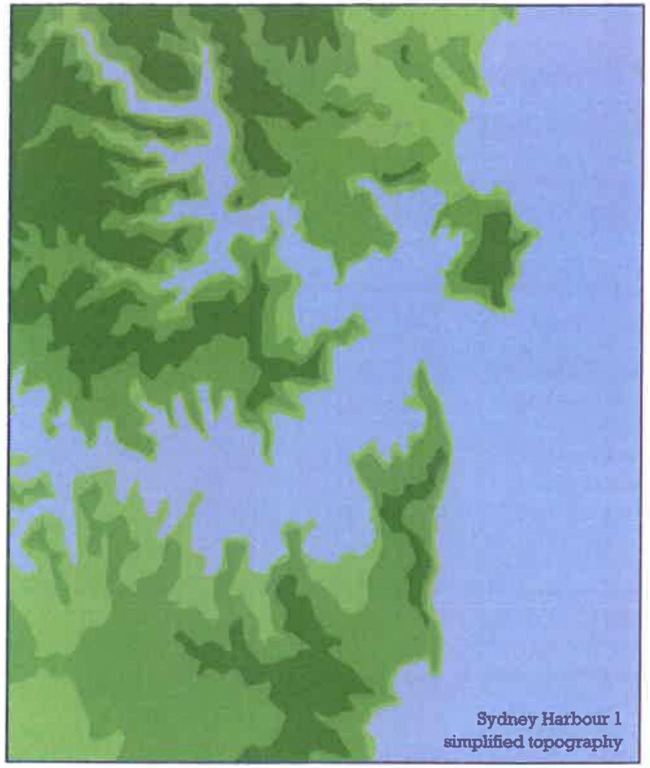
As the sun goes down, the land cools, the pressure over Spain recovers and the wind on the coast drops to what it had been earlier in the day.



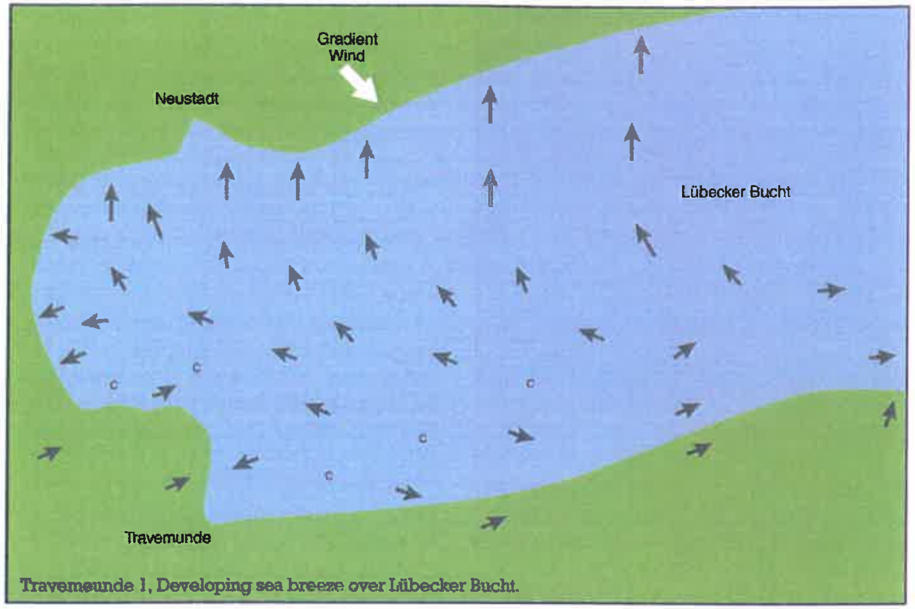
SYDNEY HARBOUR

Sydney Harbour, venue for the 2000 Sailing Olympics, can rightly claim to be the best-researched sail racing area in the world. Comprehensive wind and weather records for 10 stations in and around the harbour for September for 5 to 10 years or more have been subjected to the most thorough analysis in support of the Olympic programmes of the home and visiting teams. Here is a selection of the more interesting findings which have general application to harbour sites anywhere in the world:

- The gradient of sea temperature from warm, about 22 °C outside the harbour, to 15 °C to 17 °C inside made it a typical winter situation, with consistently fresher winds outside, and not such a clear connection as one is used to between the wind outside and the wind inside. In fact when there was a southerly surge – see Chapter 13 – it was little short of amazing to see how little connection there was between the southerly wind over the warm water along the coast and events inside the harbour.
- One course in particular, the one just inside North Head, was greatly affected by the stability of the air mass in an easterly wind. In stable air the wind went round the headland, in unstable air it went over the top, giving totally different wind patterns in the lee.
- For courses inside the harbour a windshift of only a degree or two could make a major difference to which side paid. This was a consequence of local wind bands generated by cliffs or headlands pivoting on the point of origin.
- In gusty conditions whether the direction backed or veered in the gusts and lulls was largely determined by the extent of clear water upwind. A glance at the harbour topography in Sydney Harbour 1 will help to understand why.
- In anticyclonic situations the strength of the sea breezes was strongly influenced by the height of the top of the temperature inversion. When the sea breeze had penetrated inland as far as the mountains, about 50 km inland, it would falter and start to split into cells.



Sydney Harbour 1 simplified topography

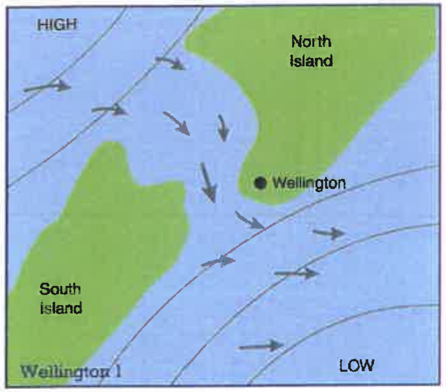


Travemeunde 1, Developing sea breeze over Lübecker Bucht.

TRAVEMUNDE

Lubeck Bay is fairly typical of a racing area with land on three sides. Winds from the north-east entering the open end of the Bay are influenced by the coasts to right and left according to the normal rules (Figures 3.6 to 3.8). When the gradient winds are blowing off either the north-west or south-east coasts on a sunny day you can work out the development and evolution of the sea breeze by asking the question "where is the air coming from to feed it?". The closed end of the Bay is obviously not a good source.

Travemunde 1 illustrates the sort of wind pattern to be found two or three hours after the start of the sea breeze when the gradient wind is in the north-west. For a south-easterly gradient the patterns are similar but in reverse.



WELLINGTON

Winds in the Cook Strait are a prime example of how, when mountains get in the way, the wind blows directly from high pressure to low pressure, getting back into its conventional stride as soon as it leaves the influence of the mountains. Wellington 1 is typical of winds in the Cook Strait, blowing straight across the isobars until they are free to be bent back by Coriolis Force. Wherever you experience a Cook Strait-type situation you are safe to assume what is in effect a very logical wind pattern, i.e. a bend either side of where the influence of the mountains is dominant.

VALENCIA

Winds at Valencia, like Barcelona, in the summer six months of the year follow a pattern typical of places:

- On a straight, flat coast
- Where an adjacent large land mass becomes hot in the afternoon
- Where gradient winds are normally fairly light.

Valencia, host to the 2007 America's Cup, was picked for the high frequency of days where winds are between 8 - 16 knots, and the very low frequency of days during the year when strong winds or stormy weather affect the area.

Situated in the south east of Spain Valencia is only occasionally affected by easterly Levanter winds, and west to south- westerly Tramontane winds which originate in the Strait of Gibraltar. A cool and gusty north-west Poinent wind may also affect the area around cold fronts.

Morning gradient less than 2 or 3 knots – any direction

The morning starts calm and the air aloft is just drifting around. Heating of the land causes the pressure to fall

overland and an along-shore gradient sets in by midday. Typical features of the wind on the water are as follows:

- It starts before mid-morning as a pure sea breeze at right angles to the coast (from between 090 and 130 degrees at Valencia), which swings to the right and increases for a while.
- The thermally –produced gradient parallel to the coast then takes over, pulling the direction round to 15 degrees from the shoreline by early afternoon (140 - 150 degrees at Valencia).
- At the same time the speed increases to around 10 knots over a coastal zone about 5 to 8 kilometres wide.
- There are few changes in direction due to the absence of any topographical effects.

Gradient wind in Quadrant 3 090 ° - 170 °

It often happens that the morning starts with a remnant of the south easterly wind of the previous day, in which case the final direction and the swings are the same as above but the speed is 5 knots or so higher. Easterly winds also swing right but not so far, and with only 2 or 3 knots increase in speed.

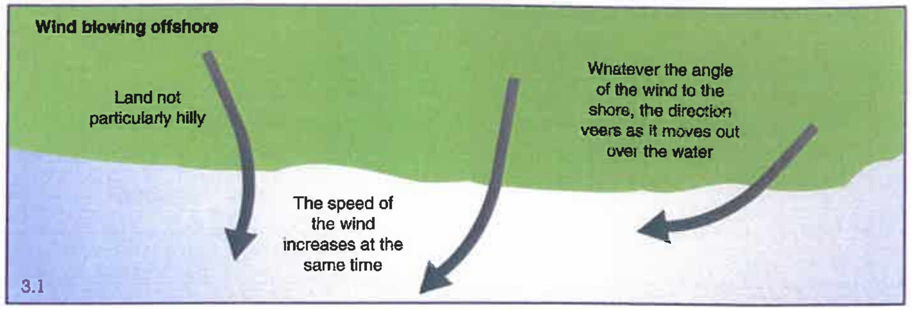
South west to westerly gradient – Quadrant 1

A Quadrant 1 gradient wind is relatively infrequent. However, when it does occur if less than 20 knots the sea breeze pattern is as explained in Chapter 8. The offshore south west to westerly wind often dies inshore early in the day, soon to be replaced by the onshore sea breeze between 140 – 160 degrees. This sea breeze is always stronger inshore, reaching up to 12 – 18 knots in Valencia.

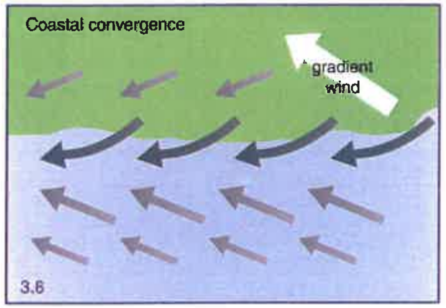
North westerly – Quadrant 2

A Quadrant 2 gradient wind is most likely to occur following the passage of a cold front: usually a weak front and barely recognizable as a front except for a change to much clearer air. A sea breeze is likely to form, offshore first, and slowly work its way inshore ending up at a similar angle but slightly lower speed to a Quadrant 1 sea breeze, 140° – 160°, 10 – 15 knots.

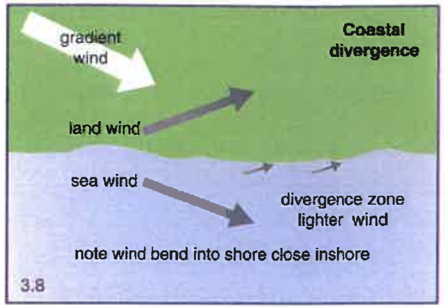
Winds near coasts



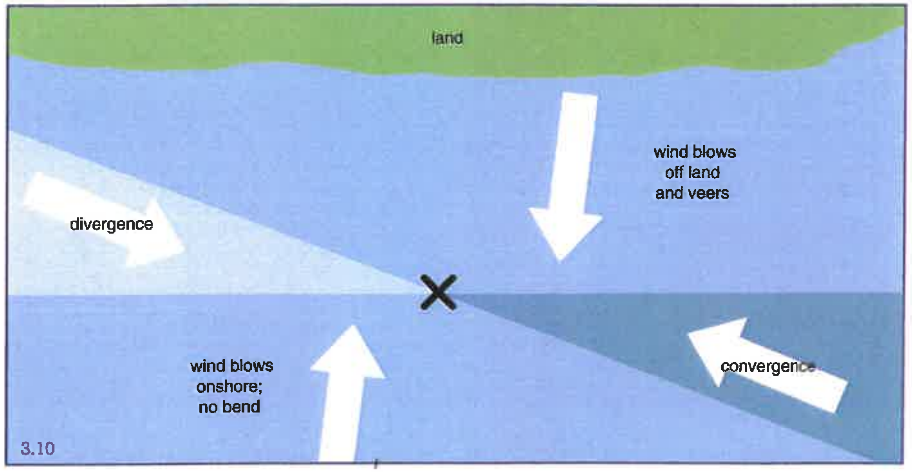
3.1 Above: with the wind blowing off the shore the wind veers and increases. On a gusty day the changes are most apparent in the lulls.



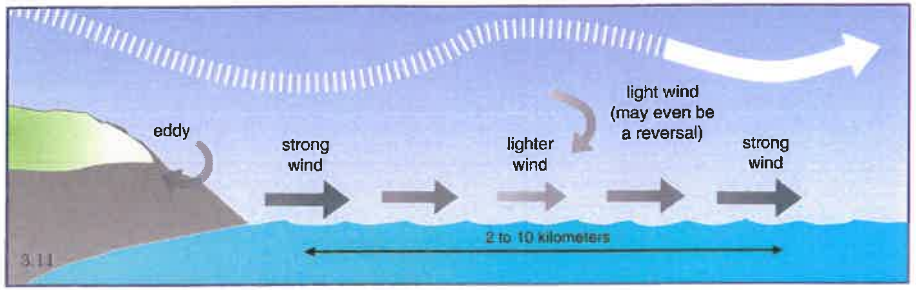
3.6 Above: with the wind blowing along the shore and the land up on your left (facing the wind) expect a band of up to 25% stronger wind 1-5 km offshore.

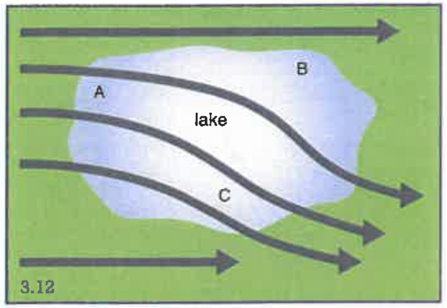


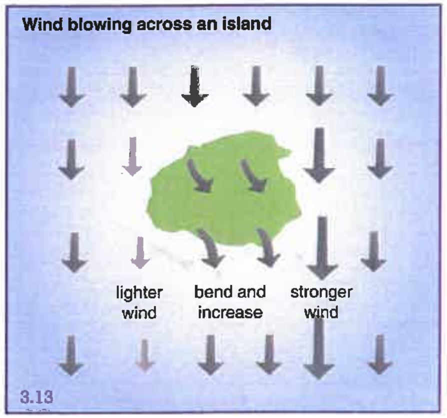
3.8 Above: with an alongshore wind and land on your right (facing the wind) expect lighter winds within 5 km of the shore, except on a sunny afternoon. Below: summary of costal effects on wind.

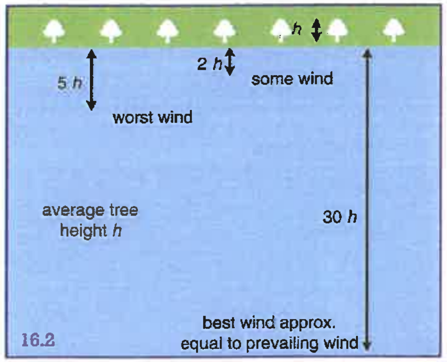


Influence of other features on the wind





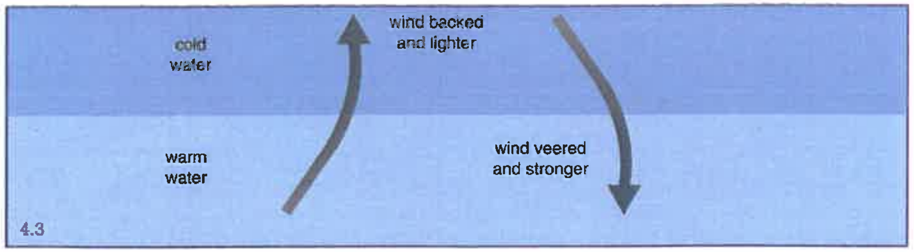




3.12 Above left: a lake wind veers as it leaves side A; divergence and lighter wind at B, convergence and stronger wind at C.

3.13 Above right: an island must be at least 5 km long for the full effect which may be felt more than 20 km downwind.

Left: the best and worst wind downwind of obstacles, related to the height 'h' of the obstacles.

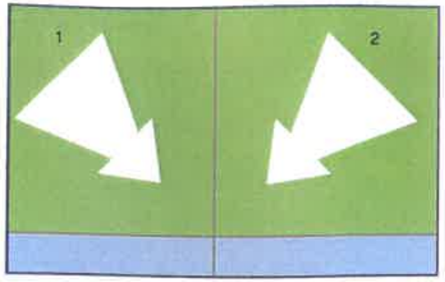


SUMMARY SHEET FOR WATERPROOFING AND TAKING AFLOAT

The sea breeze

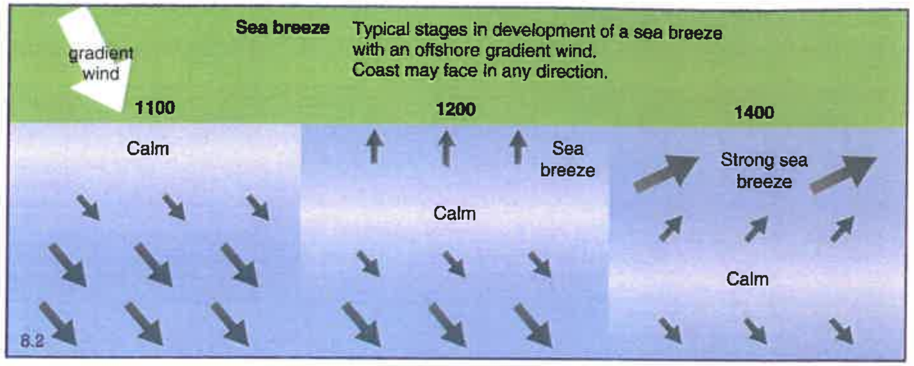
Summary and signs

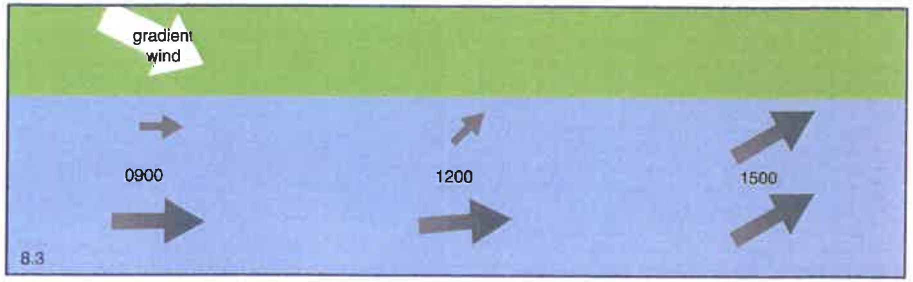
- Clear morning sky, or thin cloud.
- Temperature over land rises above sea temperature.
- Cloud offshore begins to dissolve.
- Initial offshore wind, if any, dies inshore.
- Gentle drift starts onto shore.
- Breeze builds and extends seawards, preceded by calm zone separating initial wind and sea breeze.
- Cloud over land, if any, more cumuliform.
- Breeze veers some 40 degrees in first hour then more slowly until 20 degrees back from shoreline.
- Strength increases; maximum Force 4 or 5 always near the shore.
- Breeze dies towards sunset.

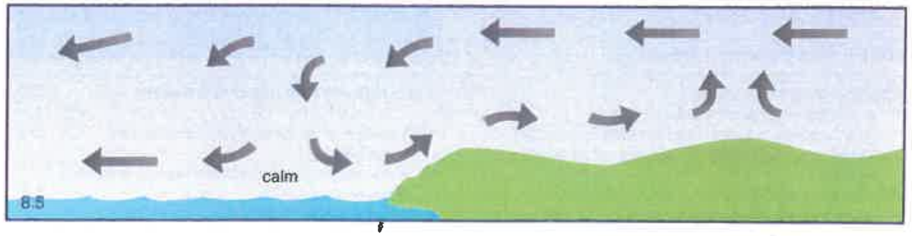


Above: The sea breeze Quadrants 1 and 2.

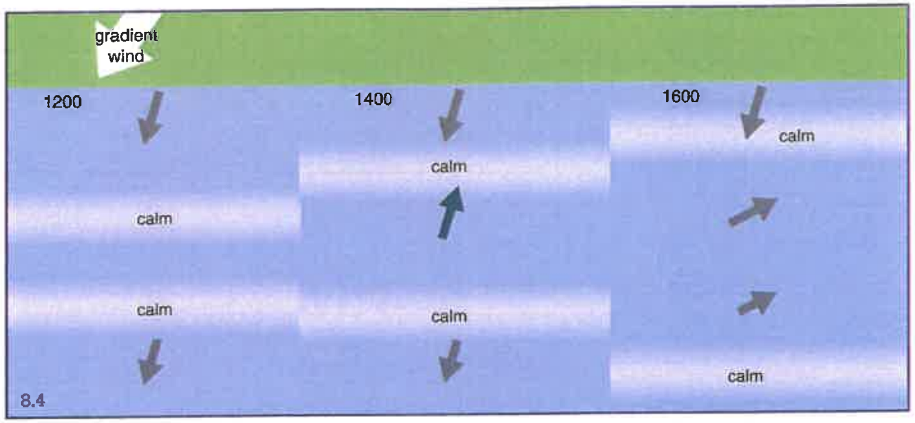
Below: the development of the sea breeze with a Quadrant 1 gradient wind. Quadrant 2 is shown overleaf.



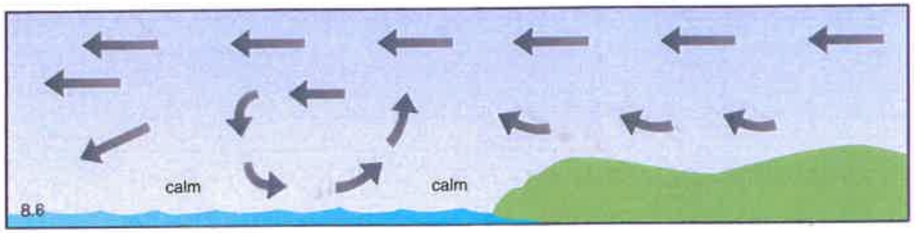




The sea breeze with a Quadrant 2 gradient wind



8.4



8.6

Afternoon wind with gradient wind onshore

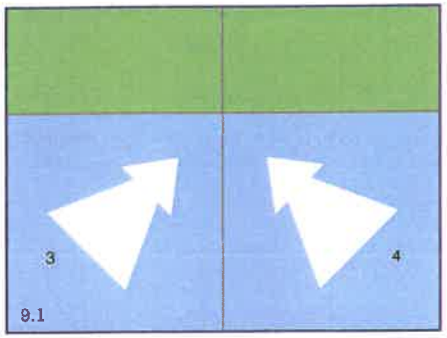
Heating of the land causes a fall of pressure which adds a component of wind of 4 or 5 knots parallel to the coast. This augments a Quadrant 3 wind especially if it is nearly parallel to the coast, but tends to kill a Quadrant 4 wind. The major differences between the enhancement of a Quadrant 3 wind and a true sea breeze are:

- The full benefit of the thermal enhancement is achieved only when the morning wind is within about 20 degrees from the line of the coast.
- The increase in speed is spread over a zone several kilometres wide.
- The change in direction depends on the strength and direction of the initial wind. It may only be a few degrees.

Will the wind increase or decrease?

Check whether there will be:

- A change in pressure gradient.
- Development of a sea breeze (offshore gradient).
- Thermal enhancement or reduction of an onshore wind.
- A change in tide.
- A band of stronger or lighter wind.



9.1

If one side pays on a beat is it due to:

- A feature of the land or an island upwind.
- A sea breeze.
- Water temperature variations across or upwind of the course
- Current or tide variations.