Dave Dellenbaugh's
SPEED&Smarts™
The digital newsletter of how-to tips for racing sailors ISSUE 151

Wind Strategies

In sailboat racing, many factors contribute to overall success. One of the major ones, without doubt, is how competitors handle wind shifts. The wind direction is always changing, and this may contribute more to gain and loss than any other strategic or tactical factor.

If we could only predict where the wind will shift next, we'd have a huge advantage over our competition. Well, actually, it is possible to predict a lot of the wind shifts that are coming our way. This requires a combination of experience, awareness and scientific knowledge of how wind works. To learn more about all this, we've enlisted the help of Chelsea Carlson, an up-and-coming sailing meteorologist who will share her understanding of the wind throughout this issue.

Interview with Chelsea

Racing advice from a meteorologist

An experienced weather forecaster who is also a racing sailor shares her unique perspective on how to sail smarter.

QUESTION: How much can racing sailors benefit from knowing more about weather forecasting?
Chelsea: Changes in wind speed and direction often have a huge impact on your finish position in a race, so anything you can do to predict future changes in the wind will be extremely valuable. I think about the 'law of the vital few,' which states that 80% of a successful outcome is due to roughly 20% of the effort. In other words, about 20% of your actions will account for 80% of your results.

In sailing, many races are won or lost due to just one or two factors such as a big wind shift or more pressure on one side of the course. Very often the 20% of the race that really matters has something to do with the wind or weather. So mastering this part of race strategy can give you a relatively significant advantage.

After I got my meteorology degree, I started using what I had learned while I was racing. Knowing a bunch of practical weather strategies consistently helped me get an advantage on the course, and this usually translated into improved results. Sure, there were occasional days when the weather didn't give us many clues to work with – but often having weather knowledge was a GAME changer!

QUESTION: Can you explain what you mean when you say you use 'practical weather strategies'?
Well, I'm not talking about the kind of forecast you get only from the internet, TV or a weather app. Sure, it's helpful to know that the wind will be blowing southwest at 10 to 15 knots when you get out to the ▶

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***Chelsea Carlson** is a meteorologist and lifelong racing sailor who recently started her own weather forecasting business called SeaTactics. As a weather coach, Chelsea's goal is to 'tie the knot' between the science of meteorology and the strategy of sailboat racing. She's the meteorologist for the US Sailing Team (including the Tokyo Olympics), and has a variety of racing experience from dinghies to one-design keelboats to offshore navigation. Chelsea founded SeaTactics to deliver weather know-how to racers who want to elevate their sailing strategies so they can gain a competitive edge. Online weather courses*

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race course. This is great for planning (e.g. what to wear and how to tune your rig before leaving the dock), but a general forecast won't help much with racing strategy. What you really need is the ability to find and understand local clues that tell you what the wind will do next in your specific race area.

For example, if you know how the wind works around clouds, you'll know where to go whenever you see them on the race course. One example occurred during a recent Etchells race in Miami. Just before the start there were lots of puffy grey clouds on the left side, but the right side remained mostly sunny and cloud-free. I knew we'd find better wind to the right and, sure enough, the top 5 boats at the windward mark (including us) had followed that plan (*see a photo analysis of this beat on pages 10 - 11*).

So, my answer is yes, the weather can definitely impact your results in a short buoy race – and as with anything in sailing, the more knowledge you have about the variables, the better.

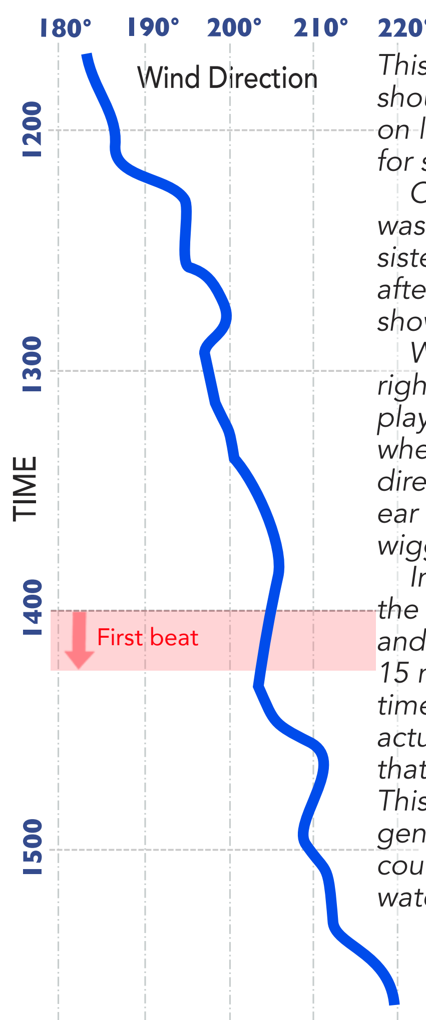
Where can sailors get 'more knowledge about the variables' so they can make better forecasts?
I recommend spending 10 or 15 minutes studying the weather before going sailing. Look at a few different sources of information including: one current weather observation (actual wind direction and speed, temperature, satellite/radar); one professional interpretation (from NOAA, SailFlow or the like); and data from one or two weather models. For near-shore coastal sailing in the US, high resolution weather models like the NAM (North American Mesoscale) or HRRR (High-Resolution Rapid Refresh) are usually pretty reliable.

It's just as important to look at what's happening in your racing area currently as it is to view the forecast. If the forecast doesn't match up with the wind and weather conditions right now, it probably won't do a good job of predicting the future.

I recently created a **Weather Resource Guide** which has a list of my favorite resources, and my recommendations about which weather models to use in various scenarios. You can download this guide for free by clicking the link above. Check out the resource links, and bookmark the ones you like so you can easily and quickly get a racing forecast.

Is it possible for sailors to create their own daily local wind and weather forecasts?
Sure, I encourage this as an alternative to relying on general weather apps, and it's not as hard as you might think. Use the link here to see a video where I describe how you can easily prepare **your own racing forecast** in 20 minutes or less. ▶

Here's Chelsea navigating on a long-distance race. The longer your race (in time or mileage), the more likely you are to see the wind trends that you'll find in large-scale marine forecasts. For shorter races, however, macro forecasts are not usually too helpful; success depends much more on the clues you see in a small area during a short period of time (which are often different from the general forecast). The shorter your race and the smaller your race course, the more you need to watch for local clues like clouds.



This chart shows why you shouldn't rely too much on large-scale forecasts for short races.

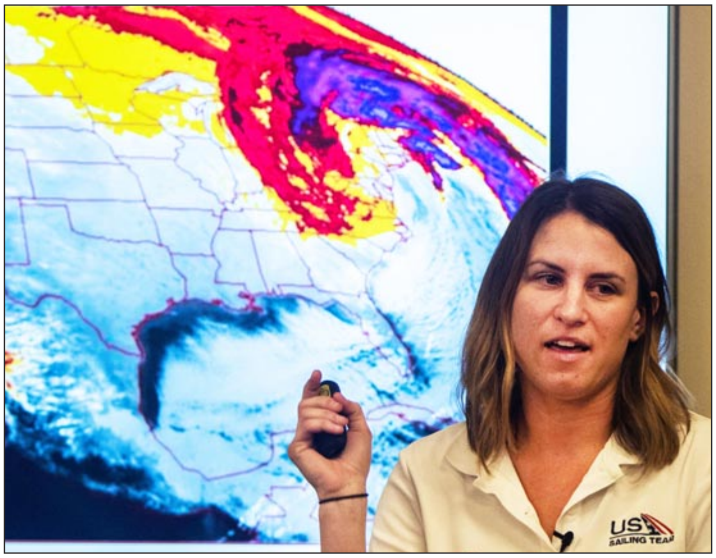
On this day the wind was forecast to shift persistently right during the afternoon (and it did as shown by the graph).

With the wind shifting right, it was tempting to play the right side. But when the wind changes direction, it's never a linear shift: there are always wiggles back and forth.

In the case shown here the race started at 2 pm and the first beat took 15 minutes. During that time, the wind direction actually 'wiggled' left, so that side was 'favored.' This was counter to the general prediction and could be forecast only by watching very local clues.

Before a race, how long do sailors need to study the wind in order to have a good understanding of wind shift patterns?
Ideally, 30 minutes to an hour on the water. Whenever possible, I sail for an hour before racing so I can estimate the cycles of wind shifts. My goal is to figure out at least 80% of the picture of how the day will play out, including a rough idea for my first-beat strategy. The 20% I don't know will typically come from things I can't figure out ahead of time such as cloud movement, location of the marks, positions of other boats and so on.

If you don't have an hour (most sailors don't), just go out as early as you can and use your time efficiently. For example, get a feel for how shifty or puffy the conditions are by tracking the wind patterns while you sail out to the course. Be careful about placing too much emphasis on data collected well before the start – this may not be valid by race time so be sure you are constantly re-evaluating. Also, be sure to watch what is going on around (and above!) you. If you notice big changes in the weather (e.g. it gets cloudy or sunny), this could impact the wind data you are collecting and using in the race.


Chelsea says, 'Keep Learning! Read as many books, articles and weather forecasts as you can. After racing each day, talk with your team, competitors and coach (if you have one) about what happened with the wind and weather that day. What clues did you see (or should you have seen) to help with predicting the wind shifts and pressure changes?'

Meteorologically, which wind pattern is more likely – oscillating or persistent shifts?
In general, oscillating shifts are more common, though it does depend on the venue and weather pattern. Oscillations are a natural, internal part of the wind and are always occurring due to fluctuations at different levels of the atmosphere. Persistent shifts happen less frequently because they are caused by some 'outside force' (e.g. a new weather system, front, sea breeze circulation, or the rotation of the Earth). Keep in mind that even during a persistent shift, the wind can still be oscillating as it changes its average direction.

If a racing sailor asked you for one weather tip that would be most helpful for their long-term racing success, what would you say?
Long-term success comes from continual learning. You can pick up some quick racing tips here and there, but my advice is to focus on learning concepts about the wind and weather. This will help you understand how the wind behaves wherever you go.

If I absolutely had to give one (and only one) word of advice, I'd probably say 'Look up at the clouds!' The clouds are full of good clues about the wind (*see pages 8 to 11 for much more on clouds*).

Is there any part of weather forecasting that sailors should not worry about so much?
A lot of people rely too much on a favorite weather app on their phone. Technology and models will generally not give you much of a competitive edge (unless you are using custom tech at a high level). An app can give you a big part of the weather picture (i.e. 'the wind direction will slowly shift right all day'), but it won't usually tell you the key, subtle information that makes the biggest difference in your race performance. That info comes from your brain on the race course when you see clouds and all the other local clues that tell you what the wind is doing.

When you're racing, how much time do you spend actually looking up at clouds?
Probably more than you'd think, but it depends a lot on my crew role. When I'm not driving, I am usually responsible for weather, strategy and keeping track of the compass numbers. I make a conscious effort to be 'head out of the boat' (i.e. looking at the sky and wind) as much as possible. One of the best times to sky-scan and think about the weather is on the sail out to the course. Then I continue this while we are tuning up, and I spend a solid five minutes watching the sky and clouds shortly before the start. During the race I've also made it a habit to scan the sky every few minutes for changes.

What are some good clues about future changes in wind speed and direction?
Sometimes there are easy clues, sometimes not. ▶

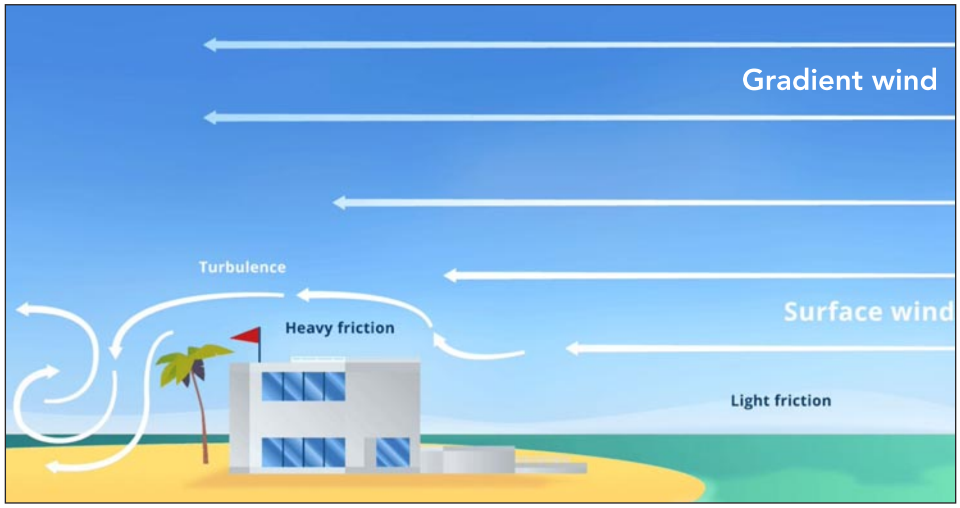
The best indicators of changes in the wind are usually clouds, which are certainly the easiest to see. If you understand how the wind works around clouds, it can be a game-changer.

For other clues you might 'feel' them rather than see them – like a change in air or water temperature, which may signal a potential change in the wind. A good rule of thumb is that warming air indicates more 'overturning' in the atmosphere, which means a higher chance of shifts and puffs. Cool air means the layers of air are more stable, so it's less puffy and shifty.

In the Northern Hemisphere, do puffs come from the right?
Yes, sometimes. Friction (over land or water) shifts the wind direction to the left near the surface. This means that winds higher up in the atmosphere can often be shifted more to the right (we call this 'wind shear'). So if you have a day with big wind gusts, there's a good chance those gusts will bring right-shifted wind down from above when the atmosphere is overturning. In the Southern Hemisphere the opposite is true – gusts often come from the left.

Is it important for sailors to be aware of the gradient wind?
Knowing the gradient wind speed and direction can be very helpful. First, the gradient is the prevailing wind you'll have if there are no thermal or other local effects. It tells you which way the wind will likely shift if those local effects get weaker (e.g. when a sea breeze dies in late afternoon).

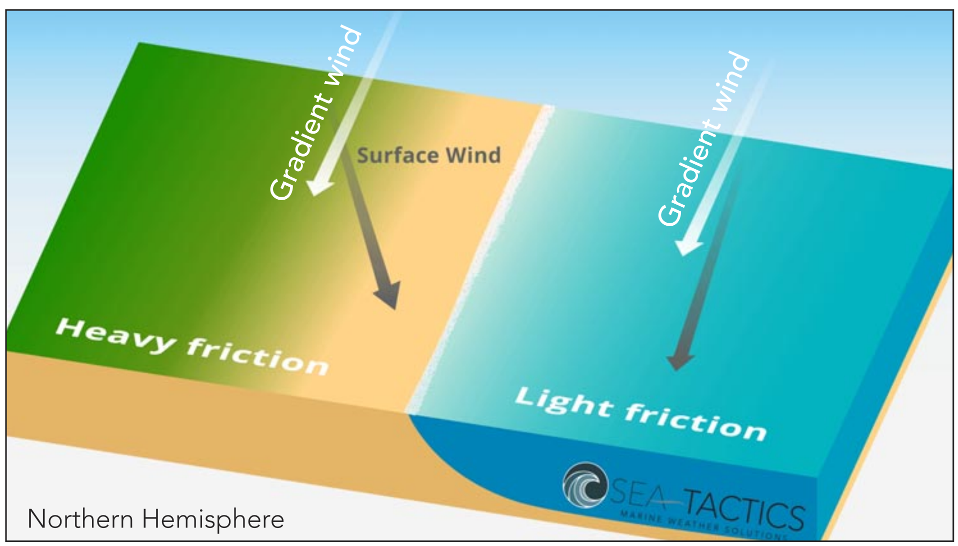
Second, when the temperature heats up during the afternoon, this causes more turbulence in the atmosphere, which in turn mixes the gradient wind with the surface wind. This could result in surface wind (i.e. your sailing wind) trending in the gradient direction. ●



Gradient and Surface Winds

▲ ***Gradient wind*** *is the wind that's far enough above the water or land surface so it is not influenced by surface friction. Think of the gradient wind as the 'big picture' wind caused by larger weather systems – it is not affected by local wind effects such as temperature (e.g. a seabreeze) or land-induced friction (see below). Gradient wind is caused by the differences in pressure shown by isobars on a weather map, and it flows mainly parallel to the isobars.*

▼***Surface wind*** *is located just above the surface of the land or water; its speed and direction are affected by friction due to trees, buildings, waves and so on. The more friction there is, the more the wind shifts and slows down.*



Many races take place in the coastal zone within a few miles of shore, which is interesting meteorologically because the wind behaves differently over land than over water. The rough surface of the land (trees, buildings, etc.) usually creates a lot more drag than the relatively smooth surface of the water. The greater the friction, the more it slows the wind speed and changes the wind direction. The wind, therefore, tends to bend more over land than it does over water. In the Northern Hemisphere (above), friction causes surface winds to back (shift left), while in the Southern Hemisphere it causes them to veer (shift right).

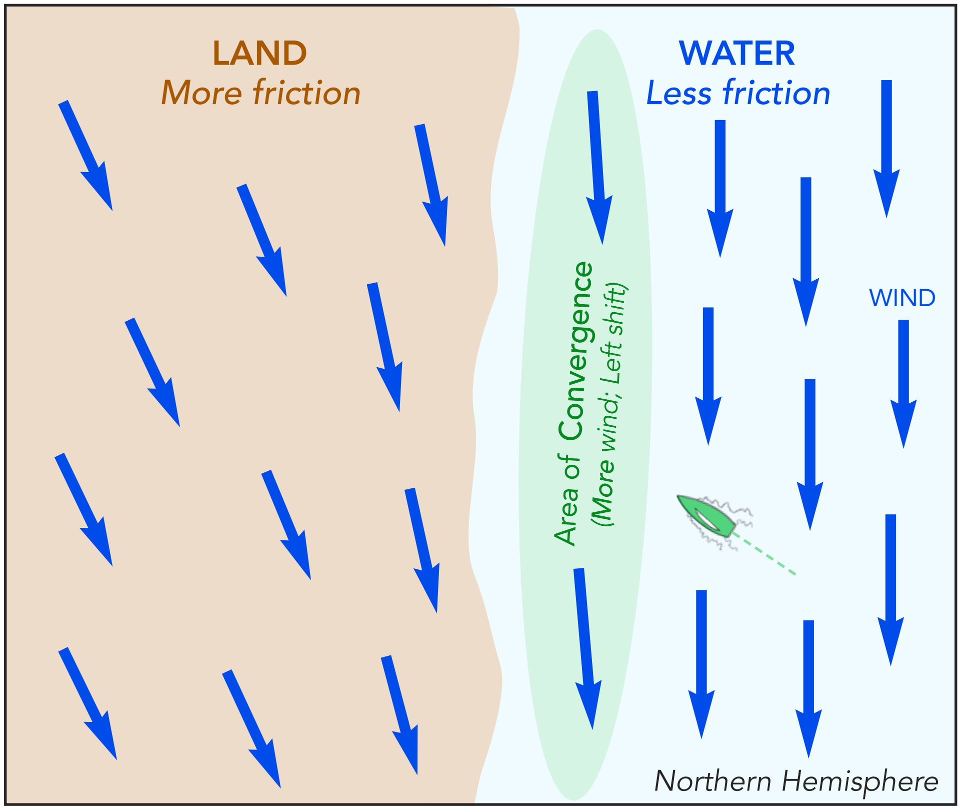
Convergence

When the wind is blowing along a shore (i.e. parallel or nearly parallel to the land), you may find an area of **convergence** close to shore. This area has more wind pressure (than farther offshore), and the direction of the wind might shift slightly so it comes more from shore (*see right*).

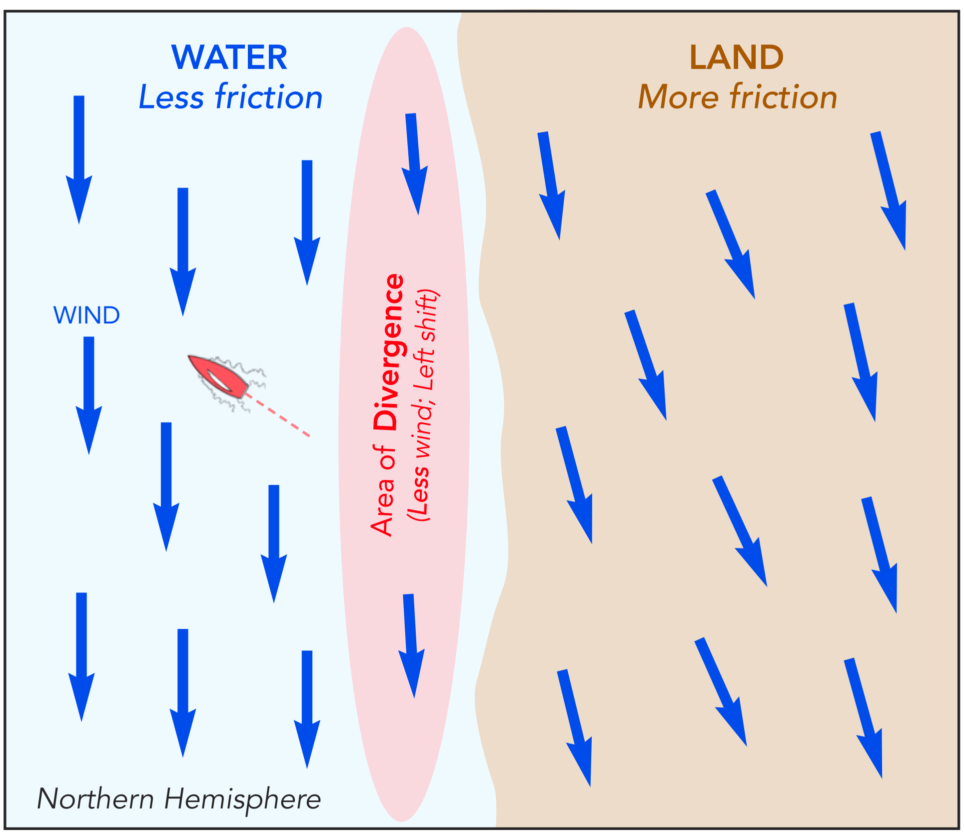
Convergence happens because the extra surface drag of the land area causes the wind to shift and blow toward the nearby body of water. This wind blowing off the land converges with the wind over the water and creates more wind where the two breezes meet.

In the Northern Hemisphere more friction makes the land wind shift left, so you'll find convergence when you are sailing upwind and you get closer to a shoreline on your left. South of the equator this is opposite: more friction makes the wind shift right so you'll find convergence near a right-hand shore when racing upwind.

When there is an area of convergence on your race course, it's usually good to head straight for this 'permanent' area of better pressure. Treat it like a persistent shift (*see page 15*).



*Because wind encounters more friction over land than over water (and because friction affects wind direction), the wind over land does not blow exactly parallel to wind over water. As a result, the 'land wind' and 'water wind' will either **converge** (above) or **diverge** (below) near shore; this effect is greatest when the wind is roughly parallel to shore and can extend as far as a few miles offshore.*



Divergence

If you find an area of convergence near a left-hand shore, you'll find an area of **divergence** near a right-hand shore (and vice versa). This area has less wind pressure (than farther offshore), and the direction of the wind might be shifted slightly so it blows more toward the shore (*see left*).

Divergence occurs because the land friction causes the wind to shift away from the nearby body of water. This means the wind blowing over the land will diverge from the wind over the water; as a result there will be an area with less wind.

In the Northern Hemisphere you'll find this when you are sailing upwind and the land is to your right. It occurs in the Southern Hemisphere when you are sailing upwind and the land is to your left.

Strategically, it's usually best to avoid areas of divergence, primarily because of lighter wind there.

Compression

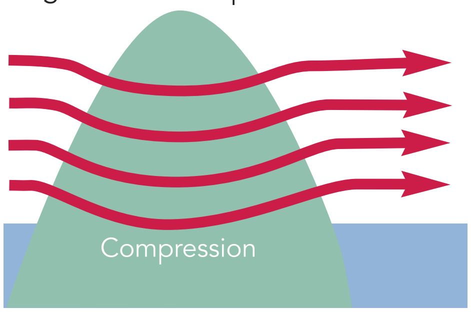
The presence of land near your race course will change the direction and speed of the wind due to the effects of convergence and divergence, but it also affects the wind in other ways.

Of course, any object like a hill, tree or building will block the wind and create a wind shadow on its leeward side. That is obviously a place to avoid, but whenever there is a wind shadow, look for a corresponding area of more pressure on either side of the object. The wind that was blocked by the object has to go somewhere, so it generally flows around the object.

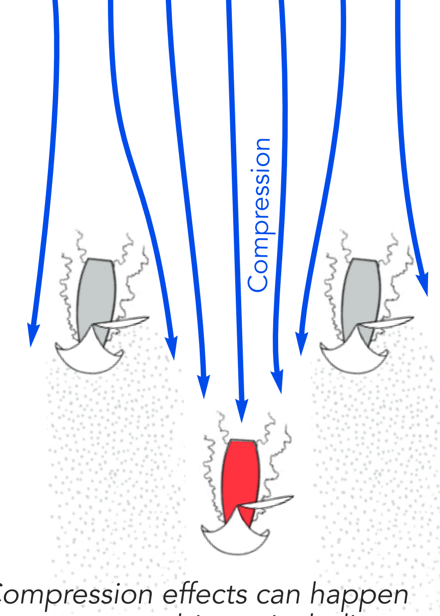
As the wind (that's aiming at the object) is deflected toward the side of the object, it meets up with wind that was already flowing in that area. These two airstreams compress together, and the result is area of stronger wind. It's similar to convergence, but the change in wind direction is caused by a blocking object, not by more friction. You may see this compression on both sides of the object, and it usually extends for a ways to leeward of the object.

The higher the obstruction, the more likely you are to see compression effects on its sides. That's because the wind is less able to go over higher objects, so it mostly has to go around them.

When you're racing, look for areas around the race area where you may find more wind due to this compression effect. A typical place would be a bluff, cliff or hill on one side of the course. When the wind is blowing roughly parallel to that obstruction you are likely to find better breeze in this area throughout a race.

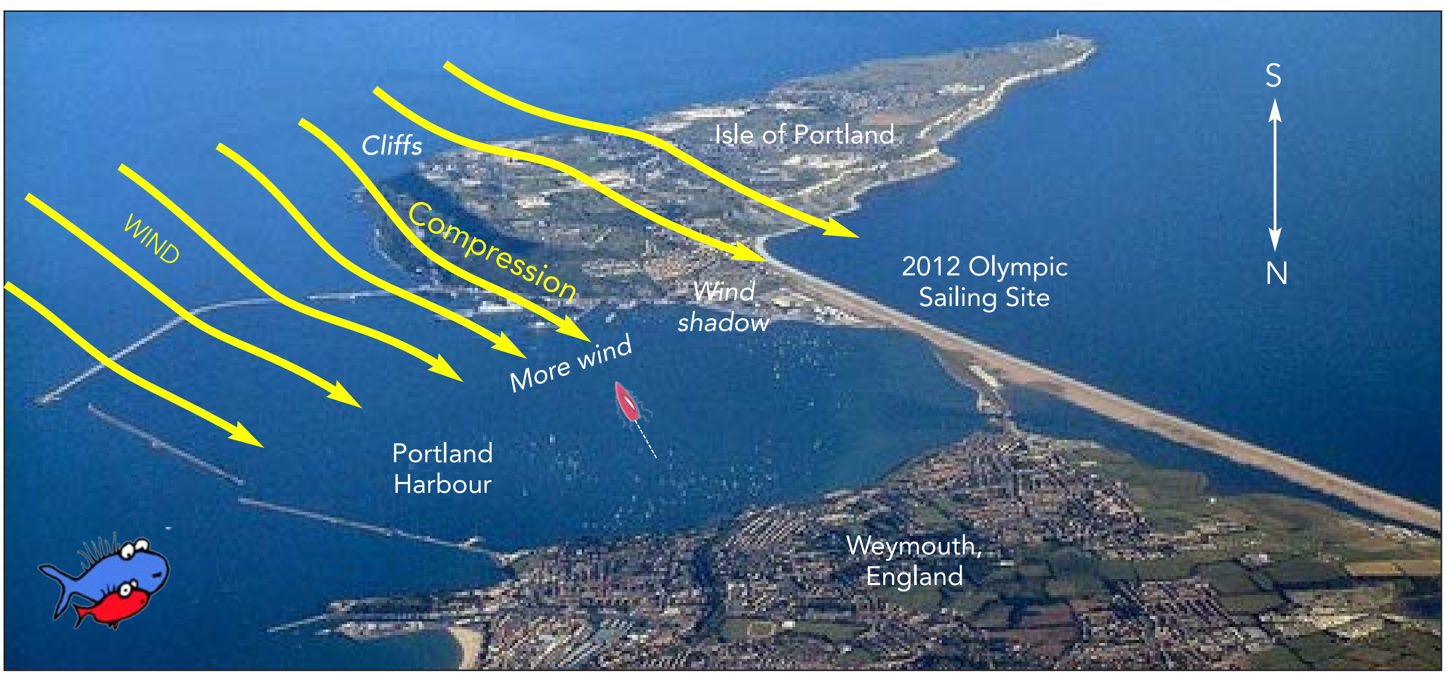


When the wind meets a hill, cliff or building in its path, some of the wind is deflected around the sides or edges of that object. As a result you'll find more wind near the sides of these obstacles, especially the ones that are relatively high.

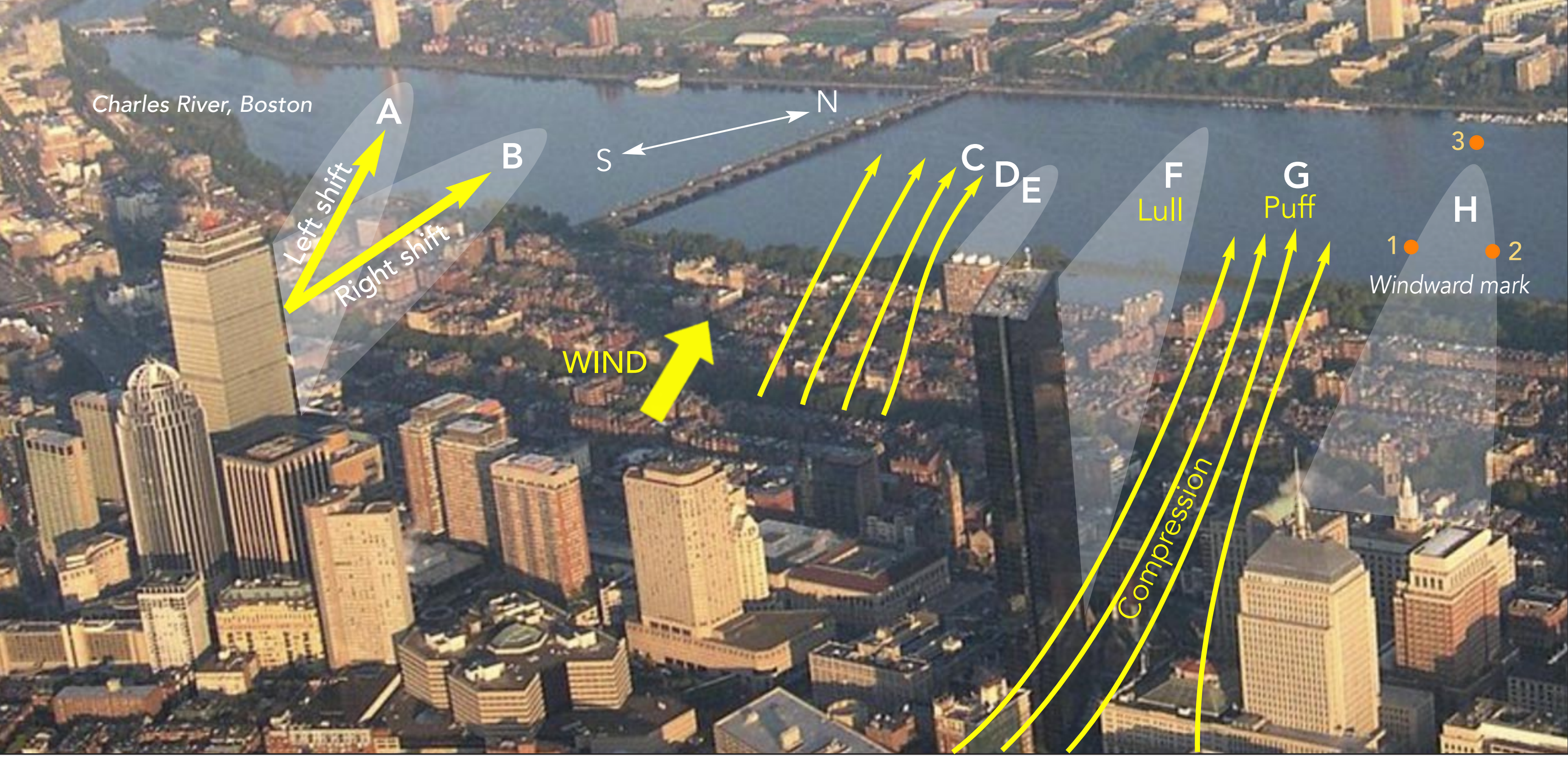


Compression effects can happen between any objects, including boats. For example, when two boats are sailing near each other on a run, the wind will accelerate through the gap between them. A boat that is to leeward and ahead of that gap (Red) often gets more wind from this compression.

However, this benefit doesn't usually last long enough to help much. If Red moves ahead very much she will sail out of the compression area. It's also likely that Red will end up in a wind shadow if the wind shifts a little or if the boats behind get closer together.



The 2012 Olympic sailing events were held in Weymouth, England, with some of the races held inside the large harbor near the Isle of Portland. This island has a long, high cliff running along its northeastern end. A typical southeast breeze flowed nearly parallel to the cliffs and created two effects: 1) a wind shadow to the northwest of the island, and 2) an area of greater wind speed where the wind bent around the cliffs. When racing in this wind direction in the harbor, it almost always paid to go right for better pressure.



Racing near land in an offshore breeze

We've been talking about how the presence of land can affect the wind when it is blowing parallel, or nearly parallel, to the coast. But what happens when the wind is blowing onshore or offshore?

When the wind blows toward the shore, there is not much directional or pressure change in the wind until after it encounters friction and/or objects over the land. However, if the wind is approaching a high shoreline (e.g. a bluff or cliff), it may start lifting up to go over the land feature before it reaches the shore. So watch out for less wind closer to land.

When the wind is blowing offshore (roughly perpendicular to the shoreline), the influence of obstacles (e.g. buildings) to windward may become more important than other factors like weather systems or clouds. The closer you get to shore, the more you must prioritize playing very local shifts, puffs and lulls. Here are some notes about sailing in a venue like the one above.

• The wind shifts may seem **random**, and that is often true with regard to their timing (so don't worry too much about timing the shifts). But the range of the shifts is usually consistent. That is, the wind shifts back and forth through a range of 20° or 30° or 40°. If you can identify the far left and right shifts, those probably won't change much. Then use your compass or nearby landmarks to know if you are lifted or headed.

• Another way to identify the lifted tack is to look where your bow is pointing relative to the windward mark. The **longer tack** is most often also the lifted tack, so sail that first (unless you have a good reason not to). This can change frequently when you're close to shore.

• The more random the wind, the more you have to go by **VFR** (visual flight rules). In other words, sail by what you see. For example, your plan for the first beat should be based on what you see one minute before the start, not on some bigger picture meteorology.

• The closer you get to the windward mark (and the shore), the more **exaggerated the wind effects** will be. You'll see quicker changes in wind direction and speed; bigger puffs, lighter lulls; and a greater range between left and right shifts. This makes it critical to look around a lot and be ready to change gears often.

• Plan for bigger shifts, puffs and lulls near the windward mark (1 or 2 above) than at the leeward mark (3).

• The closer you get to the windward shore, the harder it is to see what's coming since there may not be much water to windward to show the puffs. So look for other clues (e.g. flags). Because the near future is often a surprise, stay in positions (e.g. near the middle) where you won't be hurt too much no matter what happens.

• **Avoid the layline** as long as possible but when you finally get there, overstand a little so you will still make the mark if you get a header or a lull.

• Is the **windward mark** near any geographic shifts, puffs or lulls? In the photo above, if the windward mark is at position 1, you'd probably approach it from the right to avoid the light air wind shadow (H); if the mark is at position 2 you'd approach from the left.

• Note that **wind shadows** may extend to leeward approximately 8 to 10 times the height of the object that created them (F). Watch for wind shadows to move as the wind direction shifts (A, B).

• Buildings (and the gaps between them) create **compression puffs** (C, G). Since the buildings don't move, you may consistently find better pressure in the same places. If you have good pressure that becomes shifty and puffy (D), it could mean you're in a transition zone near a wind shadow, so be careful.

CLOUDS as Clues

Chelsea: You could say clouds are a sailor's best friend because they tell us so much about what the wind is doing at any time. The clouds are visual representations of the air flow on/around our race course, so it's important to understand what clouds mean, and keep an eye on them.

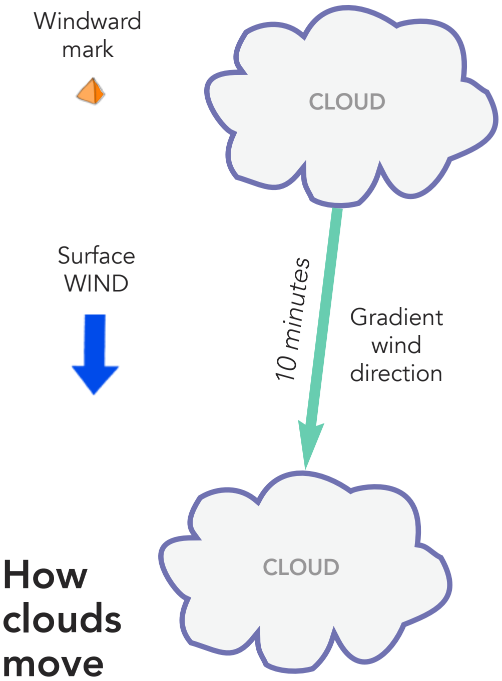
Scanning the sky at regular intervals (before and during a race) seems like such an obvious thing to do, but it's surprisingly easy to forget when there are so many other variables going on in sailing! One suggestion is to make it a priority to check the sky at certain intervals; if necessary set a repeating watch timer to remind you.

Before leaving the dock, take a look at the sky at least every 20 minutes. On the sail out, check the sky more frequently and make a mental note of: a) areas with more or less cloud cover (e.g. which side of the course has more clouds or more blue sky?), and b) clouds that may be moving into or out of your racing area.

In the buildup to the start of the race, scan the sky every five to ten minutes for changes in cloud cover or activity. By doing this at a regular interval, you can estimate the speed of the clouds in relation to the course length, and the direction in which they are moving downwind. This will allow you to make a 'nowcast' about which clouds will affect the course area during your first beat (*see right*).

Another goal of your pre-start warm-up is to sail upwind toward clouds and measure the wind shifts and changes in pressure as you approach them. How much more wind do you get on the leading edge of a cloud, or on its right or left side? And what effect do clouds have on wind direction?

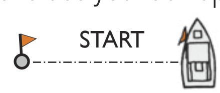
See the next few pages for more on what to look for in clouds.

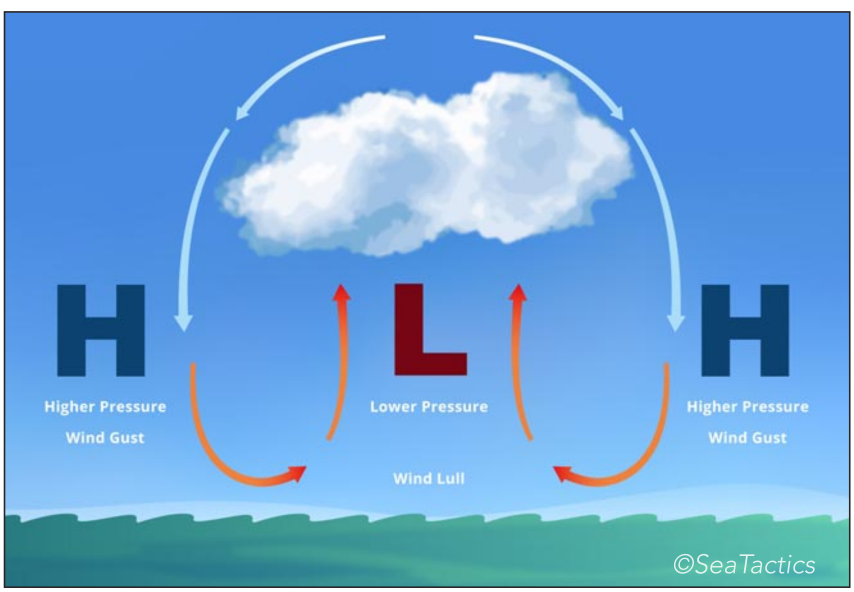


How clouds move

One reason to watch clouds is so you can predict which ones will impact your first beat. For example, if a cloud moves half the length of the course in 10 minutes, and it takes you 20 minutes to sail the beat, you will meet in the middle with any clouds that are near the windward mark when you start the race.

Note that clouds do not always move straight downwind, so that's another thing to track. Clouds are usually high enough to be up in the gradient wind. Since the gradient direction is typically to the right of your surface wind (in the Northern Hemisphere, due to friction), the clouds will often move slightly right to left as you look upwind.





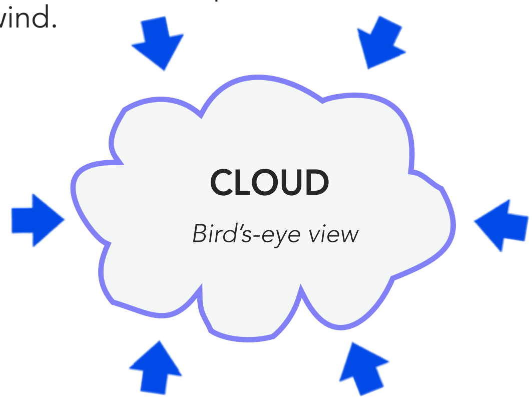
An individual cumulus cloud is essentially its own small circulation system with relative areas of lower and higher pressures (rising and sinking air). The cloud begins with air that is warmed near the water or land surface. As this warm air rises, it reaches a certain height in the sky where the moisture condenses and forms a cloud.

While the air directly underneath the cloud is rising, there is relatively lower pressure there, which creates a wind lull.

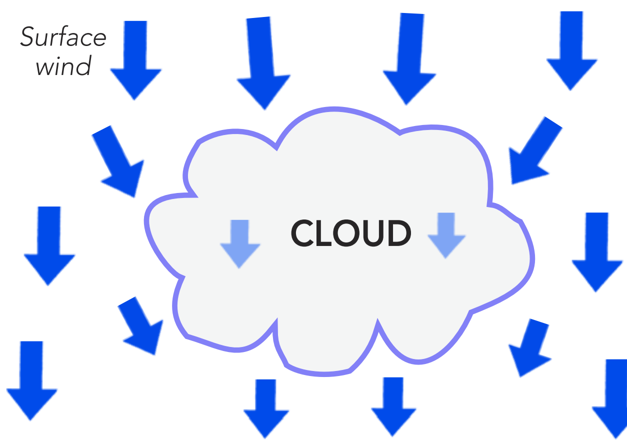
On the edges of the cloud, the air is slightly drier and the moisture evaporates (which causes cooling). This cooling air sinks around the sides of the cloud, which creates a relative high pressure area and produces a wind gust (under the blue sky).

Clouds without rain

These are the standard white or greyish cumulus clouds that we often find over land or water. These clouds show us the areas around the race course where a) local warm thermals are rising (updrafts), and b) there is lower pressure, and therefore usually less wind.



▲ As the air under a non-raining cloud rises up, the air around the cloud at surface level flows inward toward the center to replace the air that is rising. That air then gets warmed, rises and is replaced by more air flowing inward from around the cloud. This circulatory flow impacts the strength and direction of the wind around the cloud as shown below.



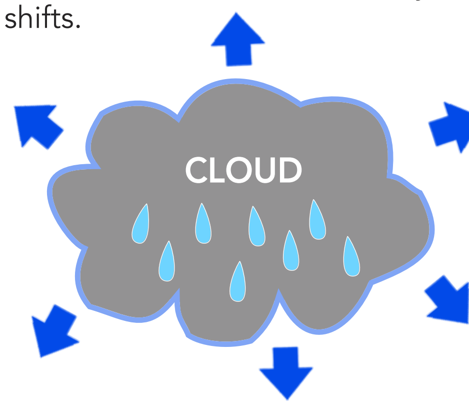
▲ This diagram shows net wind speed and direction at the surface around a non-raining cloud that is moving roughly in the direction of the surface wind. Each wind arrow is a vector sum of wind created by cloud circulation (top) and the prevailing surface wind.

As you can see, surface wind speeds are slightly accelerated on the back edge of the cloud due to the inflow enhancing it. This might be a good place to sail for, but it's tough to get there without the risk of getting caught in light air under the cloud.

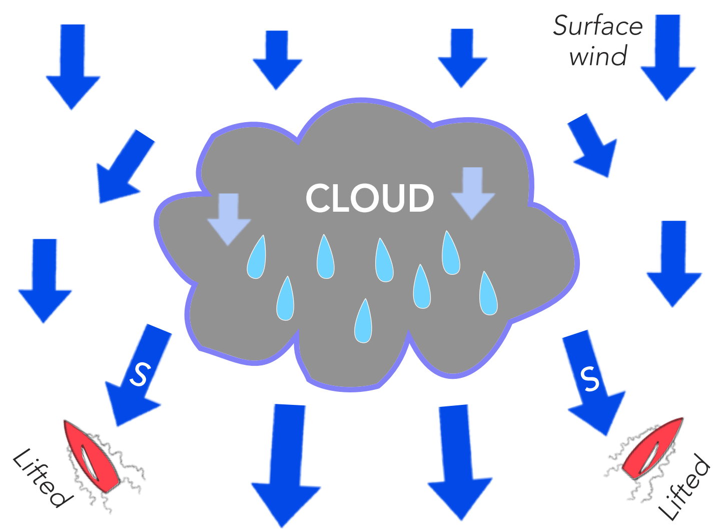
There is also lighter air in front of the cloud where the inflow goes counter to the surface wind. Avoid this area for two reasons: 1) the light wind, and 2) the likelihood of getting sucked into more light air underneath the oncoming cloud.

Clouds with rain

Cumulus clouds sometimes develop into bigger, greyer clouds with rain. Rain is an indicator that the airflow under the cloud is no longer rising (updraft), but has started to fall (downdraft). The edges of these clouds show us where there may be gusts and/or shifts.



▲ When a cloud starts raining, it's a clue that the updraft under the cloud has changed to a down-draft. The air flowing down from the cloud hits the surface and then turns outward in all directions away from the center. This air flow impacts the strength and direction of the wind around the rain cloud as shown below.



▲With rain clouds, sailors will find the strongest winds at the leading (leeward) edge of the cloud, where the outflow from the cloud adds to the exist-ing surface wind. Just downwind of the cloud is a good place to be, but don't get caught under the oncoming cloud where there is less wind (and rain).

There are also gusts on the sides of the cloud (S), and these often bring a slight to moderate shift in wind direction as the wind flows outward from under the cloud. Boats can get a lift up either side of the cloud – this is one good way to make progress upwind and avoid the cloud as it moves downwind.

Rules of thumb about clouds

A rule of thumb is "a broadly accurate guide or principle, based on experience or practice rather than theory." Here are some broadly accurate guidelines (not necessarily true all the time) that may be helpful when looking at cloud clues across the racing area. Also, we are talking here about distinct, individual cloud cells – not, for example, a solid layer of clouds covering the entire course.

• **The lower the cloud base, the more it will affect surface wind.** There will be a bigger lull (i.e. lighter wind) under a low cloud as compared to a high cloud. A non-raining cloud with a lower base will have more wind pressure at its leading edges than a higher cloud, and it is more likely to change the wind direction.

• **The darker the cloud, the more it will affect surface wind.** There will be a bigger lull (i.e. lighter wind) under a dark cloud as compared to a lighter or whiter cloud. The photo below shows dark clouds that are having a relatively big effect on the boats nearby.

• **The bigger/taller the cloud, the more it affects surface wind.** There will be more of a lull (i.e. lighter wind) under a large cloud than under a small cloud (both rain and non-rain clouds). A big/tall cloud with rain will have more wind pressure at its leading edges than a smaller rain cloud, and it is more likely to change the wind direction.

• **The lightest wind is directly underneath the cloud.** The strongest wind is usually around the edges of a cloud, and the weakest wind is directly underneath it. This is true whether the cloud is raining or not.

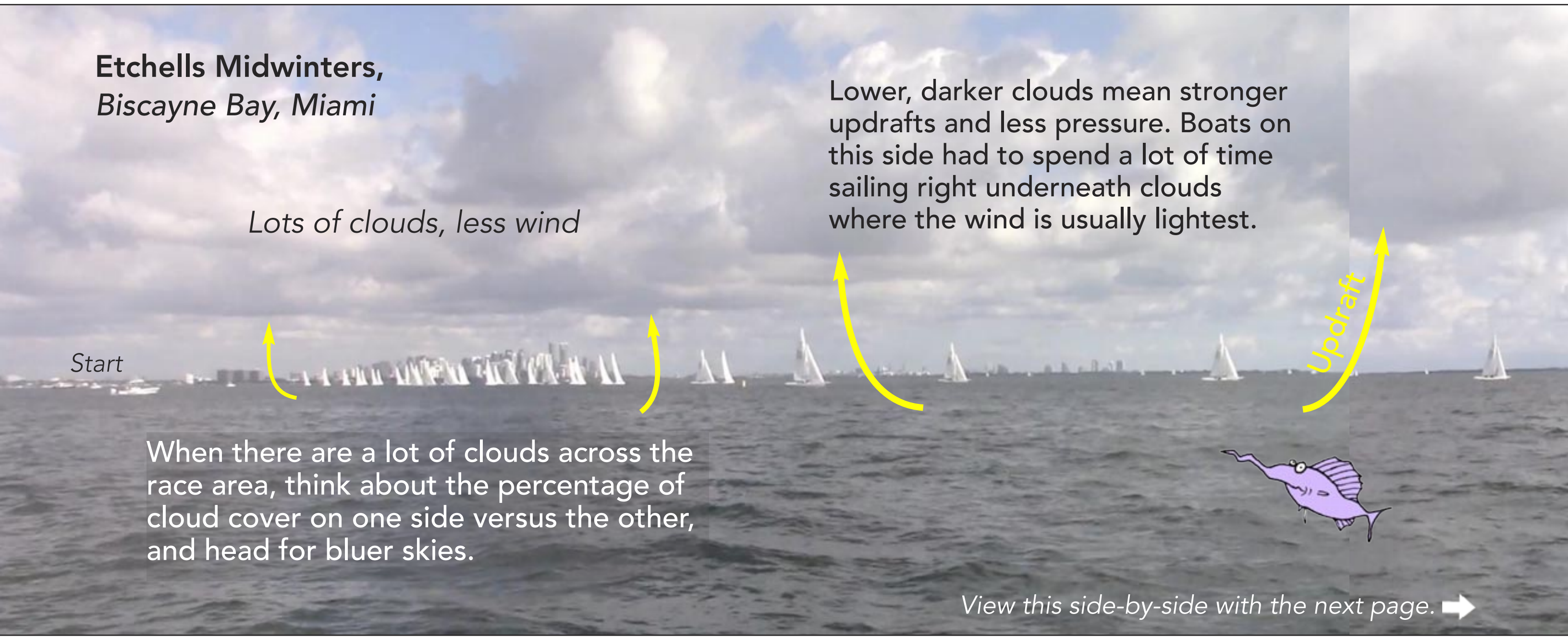
• **More rain will have more impact on the surface wind.** Clouds with lots of rain have stronger downdrafts, more wind blowing out from their edges and a greater chance of changing the prevailing surface wind direction there. They still have light wind underneath, so try to avoid sailing into the rain.

Sailors must act like detectives and continually look for clues around the race course to help them understand what the wind will do next. Clouds provide great clues!

<u>Case Study</u>

Etchells Midwinters
Biscayne Bay, Miami

The photo below (*continued on the next page*) offers a panoramic view of the Etchells fleet shortly after starting a recent Midwinter race. This is a great example of how clouds can provide valuable clues about the wind. In this case, any sailor who watched the sky leading up to the start could see there were many more clouds to the left and more blue sky on the right side of the first beat. Sure enough, there was more wind to the right, and the boats that went there came out way ahead of boats on the left. ▶



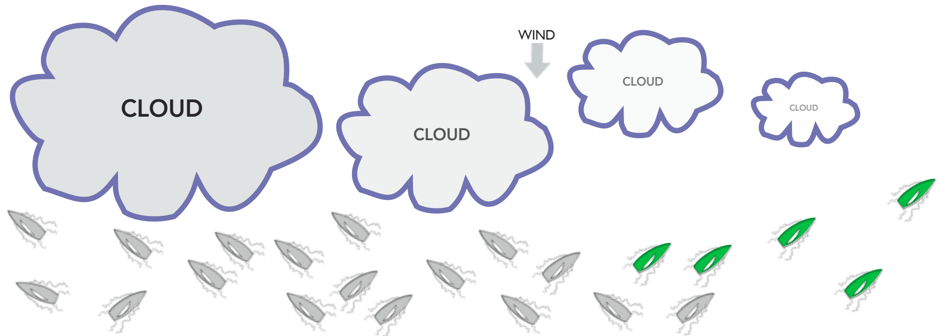
View this side-by-side with the next page. ➡

Case Study *(continued)*

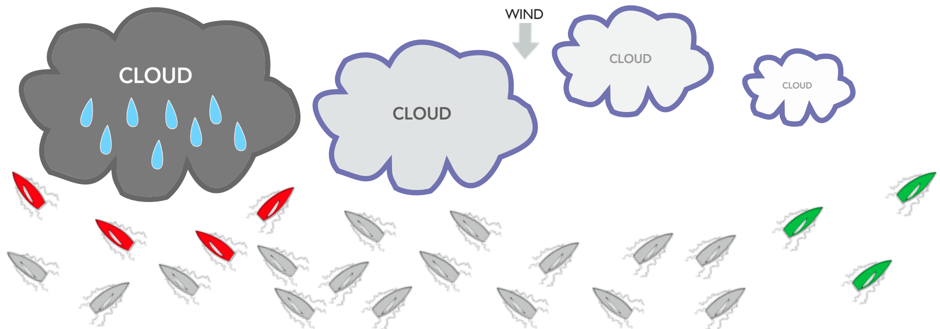
This diagram (right) shows roughly what was happening at the beginning of the race pictured below (and on the previous page). As the fleet began sailing up the first beat, there were non-raining grey and white clouds extending from the left corner of the course to the right corner. The clouds on the left side were relatively bigger, darker and lower. The clouds became increasingly smaller, lighter and higher toward the right side until there were large patches of blue sky in the right corner.

What if there was rain?

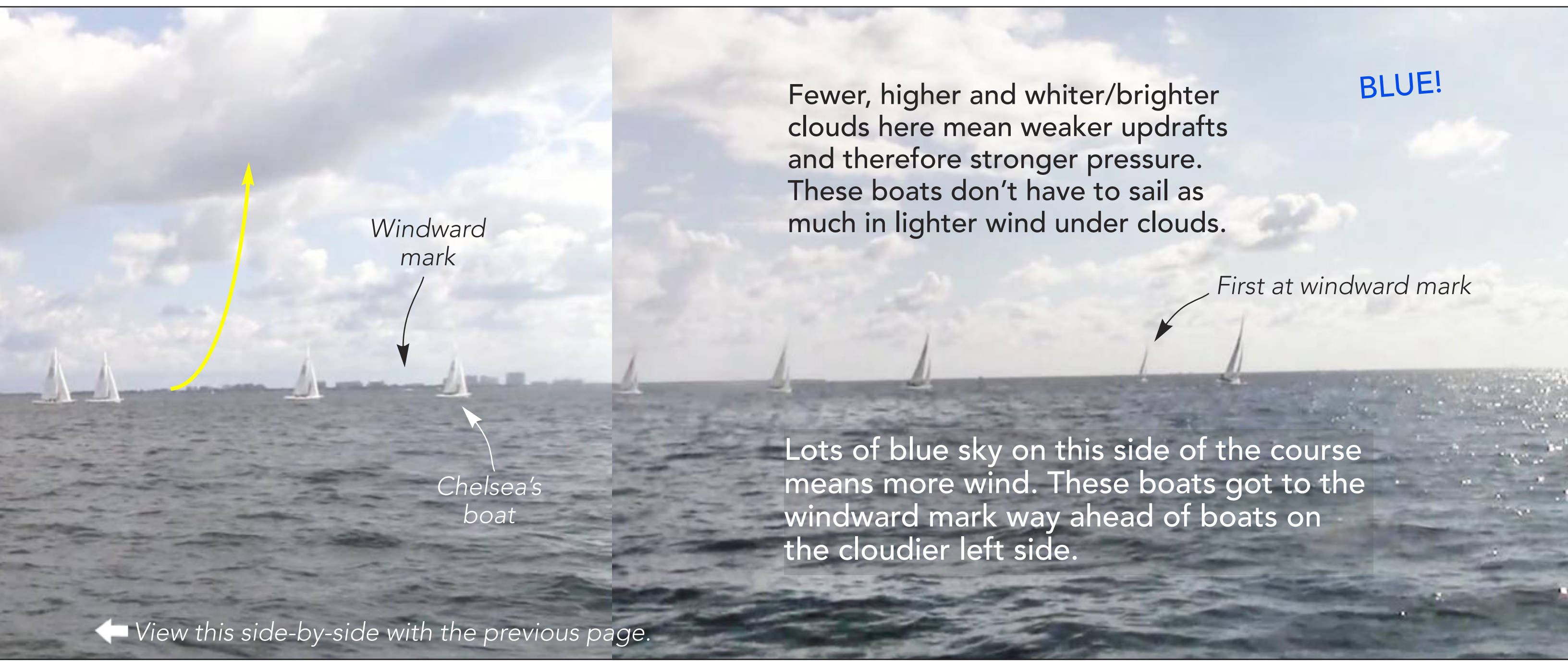
If the large cloud on the left had been a rain cloud, this might have affected the favored side of the course. A rain cloud creates more wind on the leading edge and sides of the cloud and also changes the wind direction there (because the wind fans out from the cloud). Would this have outweighed the advantage of extra pressure under blue sky on the right side? That's the big question! It depends on the strength of the rain cloud (darker, lower and more rain equals more wind), how fast it was moving and how much time boats on that side would have to spend sailing in lighter air underneath any cloud.



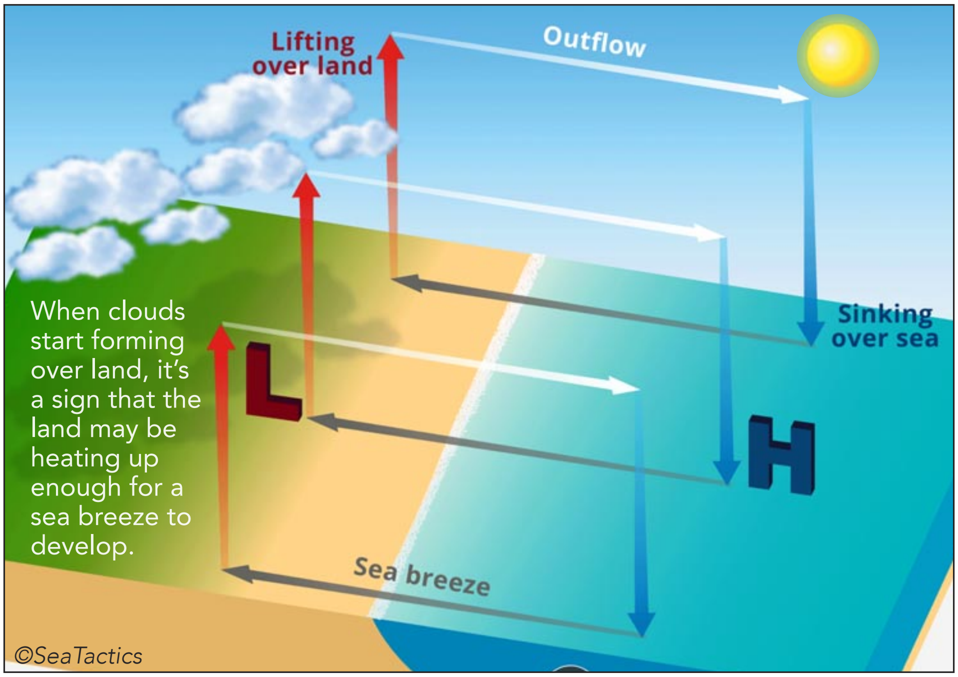
▲ *Before the start of the race, some boats (green) noticed more blue sky on the right side of the course. They predicted (correctly) that fewer clouds to the right would mean more wind there, and they raced toward that side. These boats got to the windward mark well ahead of boats in the middle and left that sailed most of the beat under more clouds in lighter breeze.*



▲ *If the cloud(s) on the left was producing rain, this could have made that side of the course stronger. Boats would find more pressure on the leading edge of any rain cloud(s), which would be especially helpful if the cloud was big and moving slowly. Those boats (red) would also be lifted while sailing up either side of the rain cloud, and it is always good to point your bow closer to the windward mark. But there isn't usually much wind under a rain cloud, so if going left meant having to sail under a cloud for very long, that wouldn't be good.*



Sea Breeze



Chelsea: Most sailors spend a lot of time racing in 'sea breeze' conditions. This wind affects coastal areas, which is where a lot of racing occurs, and it develops from late morning until mid-afternoon, which is when most people go racing. So it makes sense that sailors spend considerable energy trying to figure out this wind.

Most people think of the sea breeze as a wind that blows from water to land. That's correct, but there is more to it. The best way to understand a sea breeze may be to visualize it as a circulation driven by convection (like boiling water).

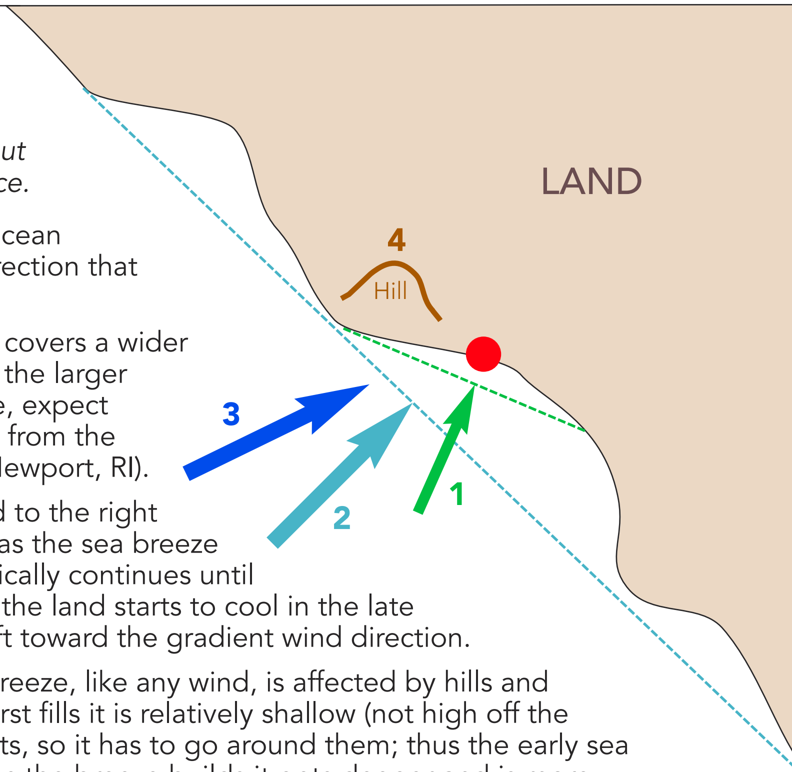
A pure sea breeze begins once the land temperature is three or more degrees warmer than the sea surface. As the land heats up, the air expands and rises (*see diagram*). This produces a local low pressure area over the land.

When this happens the sea is cooler than the land, so the air there is sinking (relatively), creating a local high pressure. Cooler air from the sea (high pressure) flows toward the land (lower pressure), causing a sea breeze. To remember how the sea breeze circulation works, think 'Lifting air over land; Sinking air over sea.'

One often-forgotten piece of the seabreeze circulation puzzle is the outflow wind at a higher altitude that flows opposite to the sea breeze at the surface.This outflow explains why the sea breeze is often very affected by the gradient wind direction and speed. When the gradient wind is blowing onshore, for example, it opposes this outflow. That inhibits circulation, which weakens the sea breeze or even prevents its development (*see more on next page*).

Factors that influence the sea breeze direction

It's helpful to know why and when a sea breeze develops, but especially useful to understand how it may shift during a race.



1. **Local shoreline** – A sea breeze usually blows from the ocean perpendicular to the coastline. Expect it to fill in from a direction that is perpendicular to the local (micro) shoreline.

2. **Larger shoreline** – As the sea breeze gets stronger and covers a wider area, it shifts (if necessary) so it's blowing perpendicular to the larger (macro) shoreline. If this is different than the local shoreline, expect either a slow persistent shift in that direction, or a quick fill from the macro sea breeze direction (like the macro sea breeze in Newport, RI).

3. **Coriolis effect** – The spinning of the Earth deflects wind to the right in the Northern Hemisphere (and left in the Southern). So as the sea breeze builds look for a slow, persistent veer to the right. This typically continues until the temperature has reached its peak in the afternoon. As the land starts to cool in the late afternoon and the sea breeze weakens, look for a slow shift toward the gradient wind direction.

4. **Local topography** – The direction and speed of a sea breeze, like any wind, is affected by hills and other obstacles near the race area. When the sea breeze first fills it is relatively shallow (not high off the water). This makes it difficult for the wind to go over objects, so it has to go around them; thus the early sea breeze direction is greatly influenced by topography. But as the breeze builds it gets deeper and is more able to flow over higher objects, so its direction and speed are less affected by local topography.

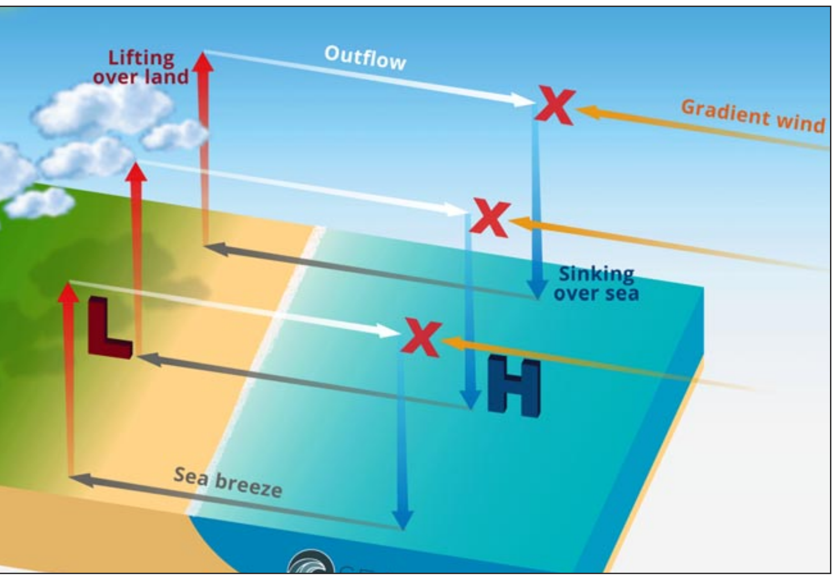
How gradient wind affects the sea breeze

As we explained on the previous page, the development of a solid sea breeze requires a circular flow of air between land and water. To balance the onshore sailing breeze there has to be an outflow of air (from land to water) above the surface wind.

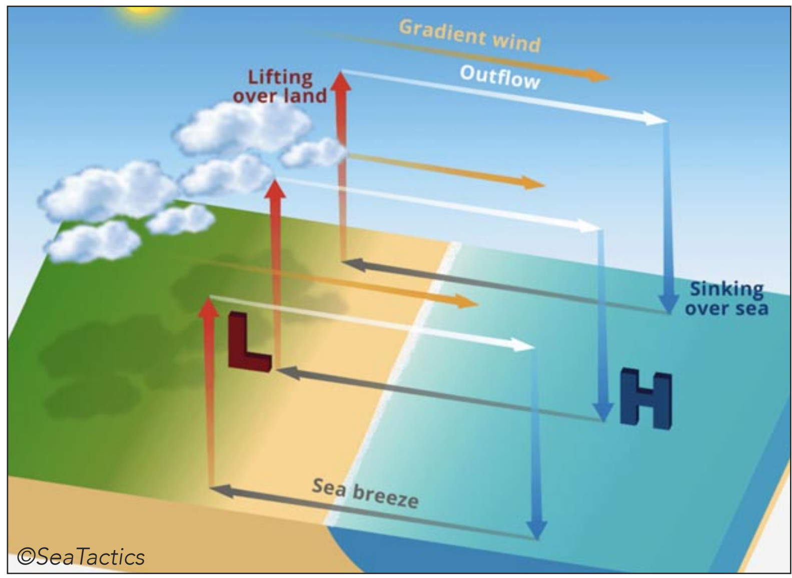
This is where the gradient wind comes into play. At first thought, it seems we'd have the strongest sea breeze when the gradient is blowing onshore, in the same direction as the sea breeze (*below left*). But an onshore gradient actually produces a weak sea breeze (or no seabreeze at all) because it fights against the outflow above the surface wind.

When the gradient wind is blowing offshore, it goes in the same direction as the outflow aloft. This enhances the thermal circulation and will usually help the formation of a robust sea breeze. The only caveat here is that if the offshore gradient wind is too strong (roughly 15 knots or more), it will overpower any thermal circulation and won't let the sea breeze develop at all.

So the two scenarios that give the best chance for a sea breeze are: 1) a very weak or non-existent gradient wind (which allows for a 'pure sea breeze'); or 2) an offshore gradient wind of less than about 15 knots. If the gradient wind does not fall into one of these categories, you will likely be sailing in a gradient-dominated breeze or a weak sea breeze that may be late to form or early to die.



Onshore Gradient *– It seems that a gradient wind blowing onshore would help strengthen the sea breeze, but the opposite is true because it fights against the outflow needed for thermal circulation.*



Offshore Gradient *– A gradient wind blowing offshore strengthens the outflow and therefore helps sea breeze formation, unless the gradient is so strong that it overpowers the thermal circulation.*

More on sea breeze shifts

Chelsea: A typical 'pure' sea breeze (without the influence of very much gradient wind) operates almost the same way every time. During the developing stages of the sea breeze, the first hints of a thermal wind start out perpendicular to the shore. Then as the sea breeze builds, there is a gradual, persistent right shift (in the Northern Hemisphere, due to rotation of the Earth).

Later in the afternoon (a little bit after the maximum temperature for the day), the sea breeze becomes fully developed. The persistent shift goes away and the wind starts to oscillate more regularly back and forth. Because the sea breeze is a 'closed' circulation system, these are small, often subtle oscillations. The wind may seem very steady, but there are usually small shifts to play.

Then as the sea breeze slowly weakens it tends to shift: a) toward the prevailing gradient direction, or b) if there is not much gradient wind, back to the left (in the Northern Hemisphere). This is one reason why it's helpful to know the gradient breeze in your racing area each day – if the thermal effects weaken (or never materialize), watch for a shift toward the gradient direction.

When you're trying to figure out which way to go in a sea breeze, adapt your sailing strategy to the stage of the sea breeze. Here's a brief summary of three stages of a 'pure' sea breeze with typical shift characteristics:

Developing sea breeze (early afternoon) – persistent shift to the right (in the Northern Hemisphere)

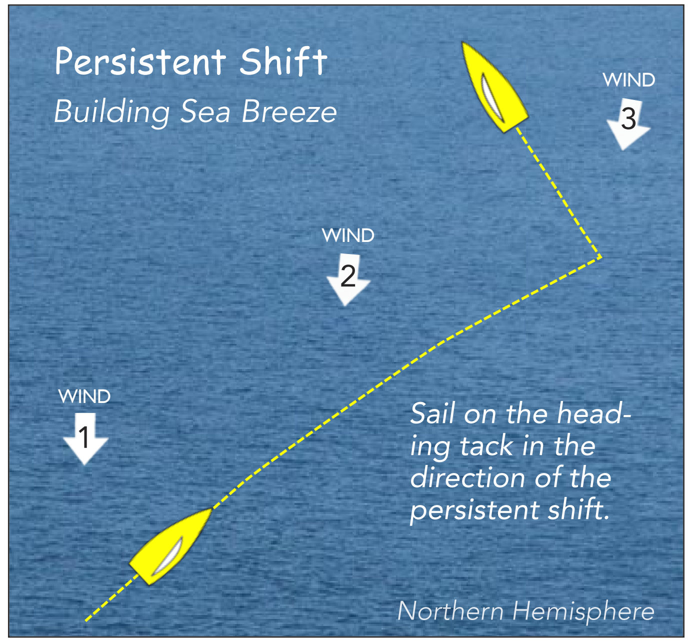
Mature sea breeze (mid-afternoon) – small oscillations

Dying sea breeze (late afternoon) – persistent shift to the left (Northern Hem) or toward the gradient direction.

Persistent shifts

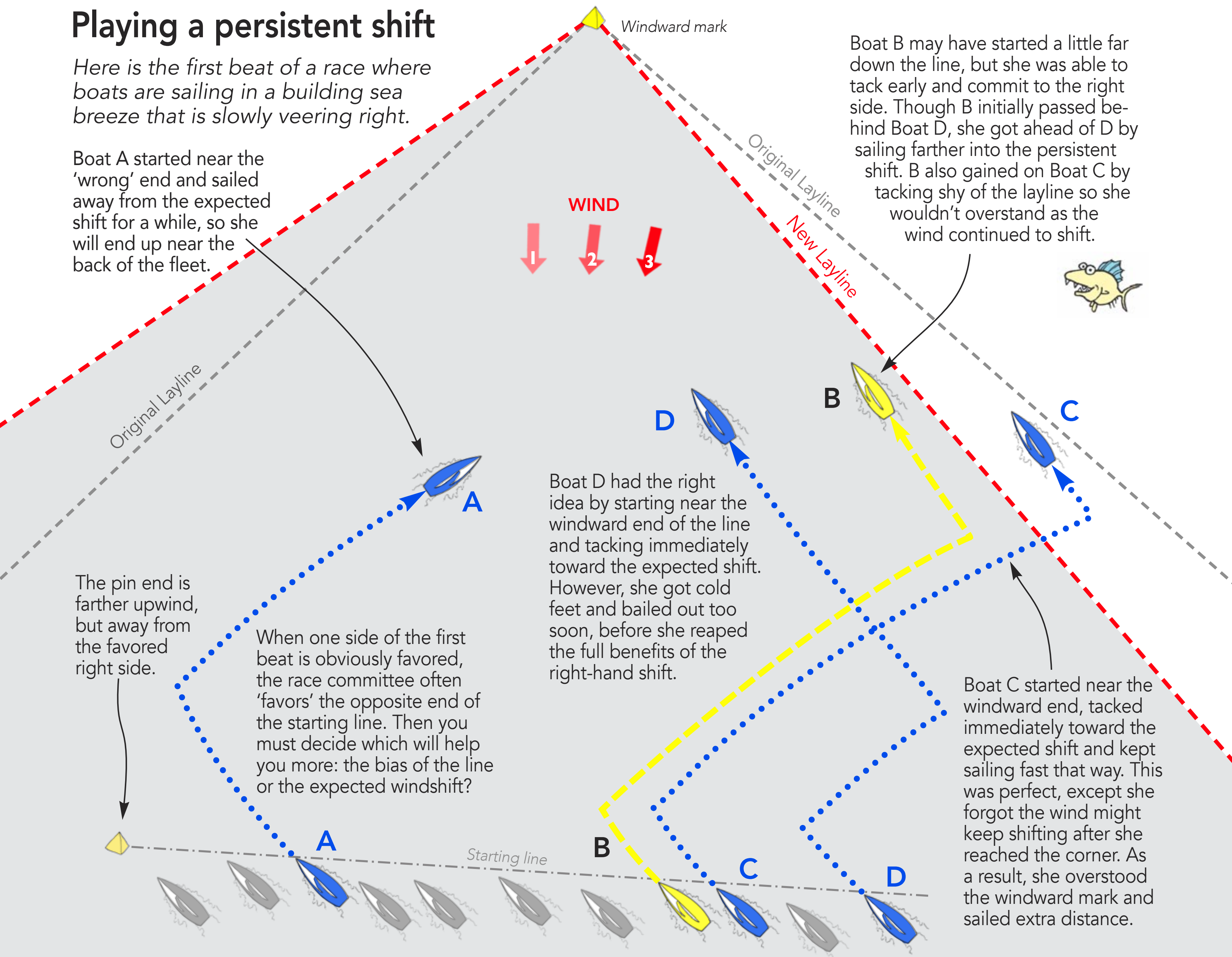
When the wind is shifting in one direction, we call this a 'persistent shift.' A sea breeze often shifts persistently while it is building, and sometimes when it is dying. Since we spend a lot of time sailing in sea breezes, what's the best way to take advantage of these persistent shifts?

The answer is relatively easy – simply head in the direction where the wind is shifting, and keep going. Don't worry about tacking on shifts or other fancy strategies – just find a clear lane and sail fast 'toward the next shift.' You must be willing to stay on the tack that is being headed continuously (which is difficult). By sailing into the persistent shift you'll end up farther to windward and ahead of boats that went the other way. But be careful not to go so far that you overstand the windward mark (*see below*).



Playing a persistent shift

Here is the first beat of a race where boats are sailing in a building sea breeze that is slowly veering right.



Persistent strategy

When the wind is shifting continuously in one direction (e.g. a building sea breeze), we use a 'persistent-shift strategy' and sail in the direction of the shift all (or most) of the way to that side. There are other times when you would use this strategy even when the wind direction is not shifting.

1. Pressure differences

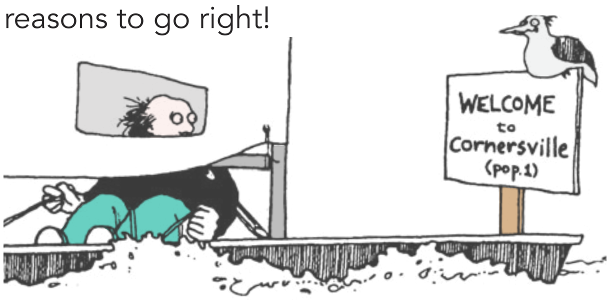
More wind is almost always better because it allows you to sail faster and higher (upwind). So when there's more pressure on one side of the course, treat this like a persistent shift and go straight there! As with most similar situations, this is a case of 'the rich get richer.' In other words, the first boats to the favored side keep getting more pressure and keep gaining on the rest of the fleet.

2. Geographic pressure and shift due to convergence

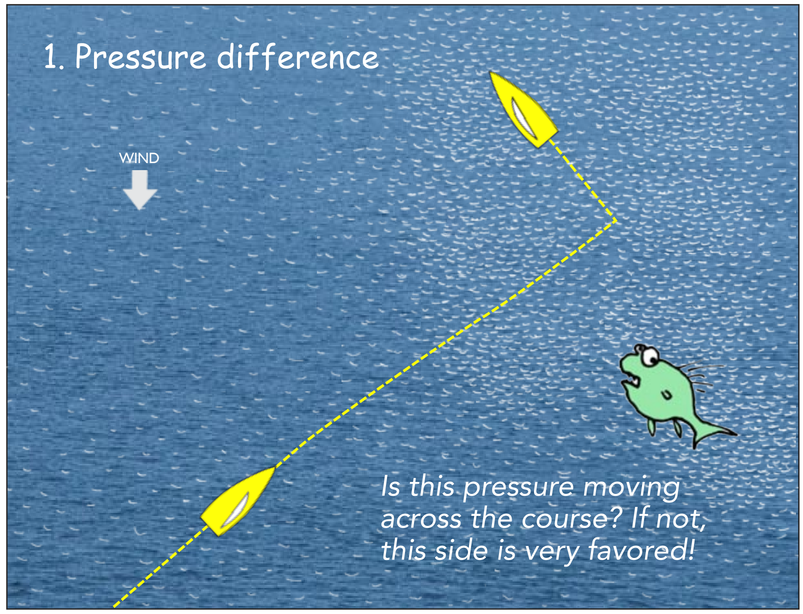
One side of the course may be favored when the presence of land there creates an area of convergence with more wind and possibly a header as you approach shore. If this is the case, treat it like a persistent shift and sail straight and fast toward the land. Sometimes it may actually pay to sail past the layline if that's necessary to get into better pressure. Note that convergence zones usually stay around for a while, so it may pay to go that way during multiple beats and races.

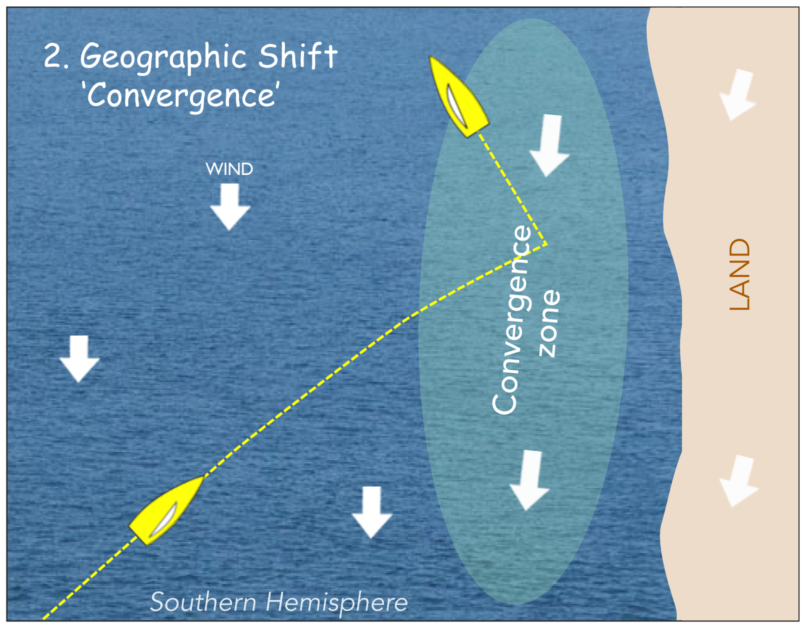
3. Differential current

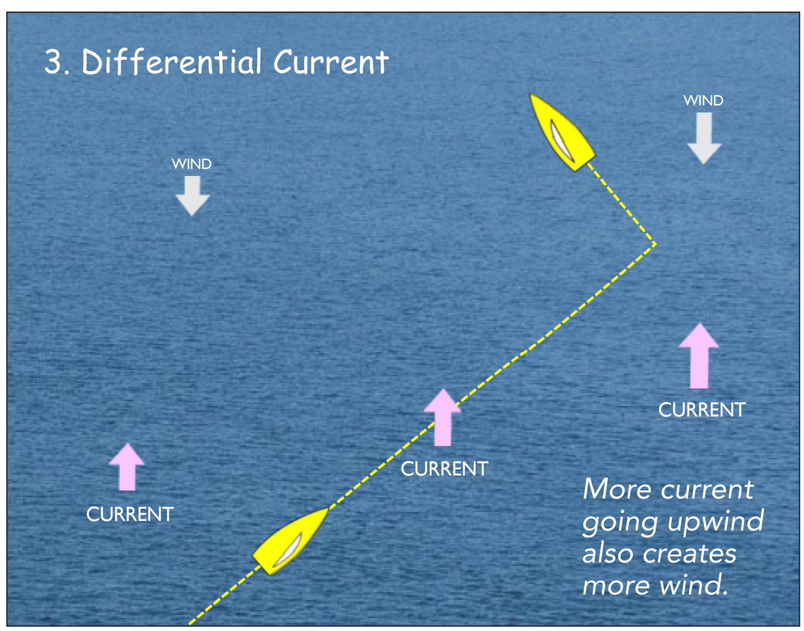
Another reason to head straight for one side of the course is a variation in current strength (or direction). If other factors are equal, treat this like a persistent shift. In the situation shown, the current gets better and better as you sail right, so go there fast. One other advantage when sailing upwind is that better current creates more wind. Two reasons to go right!



When you're following a persistent shift strategy, don't be afraid to commit hard to one side (though maybe not all the way to the corner).

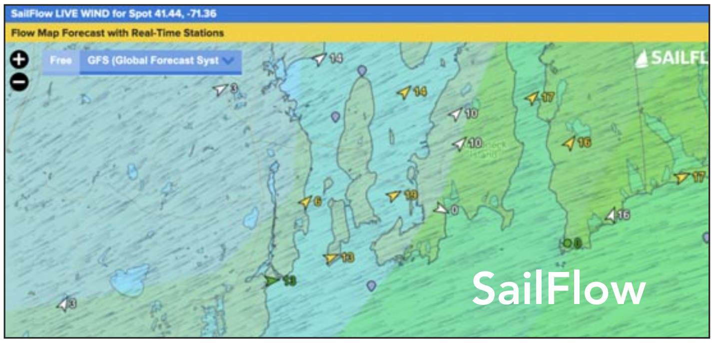




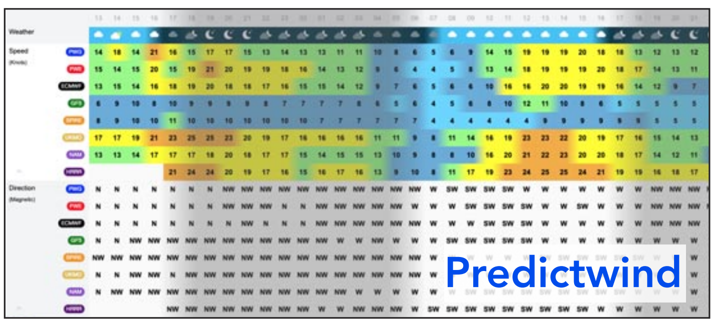


Dave's favorite wind apps

There are lots of good web sites and apps that can help you forecast the wind for your upcoming race. Two of my favorites are the popular SailFlow, and PredictWind. Both have websites and apps, plus free and paid versions. Like other similar sources of wind info, neither is a substitute for personal data collection in your local racing area, but both have some very good data and cool-looking graphics.



Sailflow I use SailFlow because it has a lot of local wind stations near me (and thus a lot of helpful 'live wind' observations), and the wind forecasts for my area seem to be quite accurate. It also has other good features like 'pro forecasts.'

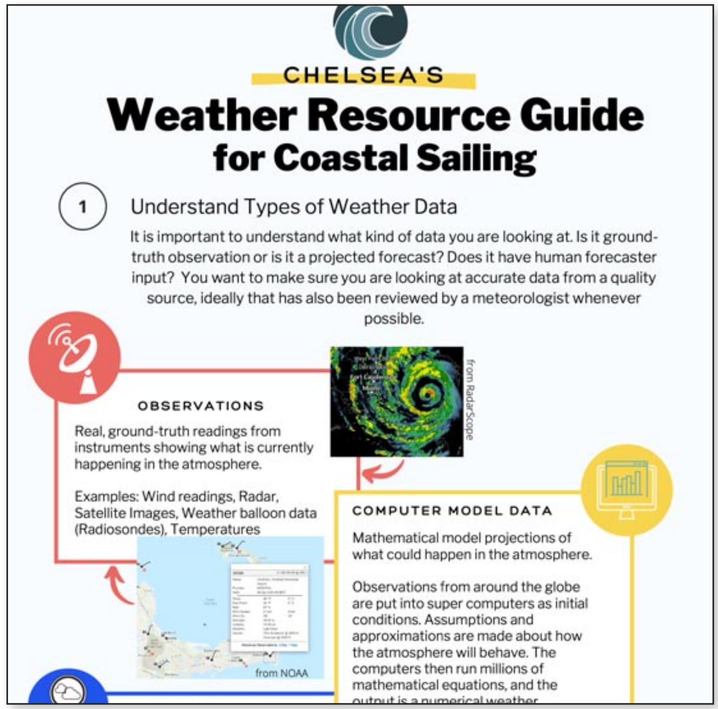


PredictWind I like PredictWind because it has a wind forecast table where it's easy to compare wind direction and speed forecasts from a bunch of different weather models (example above). It also has tons of other useful weather info.

Dave racing a Thistle with his daughters; everyone looking ahead at clouds and wind on the water.

Resources from Chelsea

Chelsea has put together a four-page PDF document called 'Chelsea's Weather Resource Guide for Coastal Sailing.' It's a great compilation of weather tips and places where you can go to get useful and accurate info for wind and weather forecasting. You can download this **Resource Guide here** for free.


CHELSEA'S

Weather Resource Guide for Coastal Sailing

1 Understand Types of Weather Data

It is important to understand what kind of data you are looking at. Is it ground-truth observation or is it a projected forecast? Does it have human forecaster input? You want to make sure you are looking at accurate data from a quality source, ideally that has also been reviewed by a meteorologist whenever possible.

OBSERVATIONS

Real, ground-truth readings from instruments showing what is currently happening in the atmosphere.

Examples: Wind readings, Radar, Satellite Images, Weather balloon data (Radiosondes), Temperatures

from RadarScope

from NOAA

COMPUTER MODEL DATA

Mathematical model projections of what could happen in the atmosphere.

Observations from around the globe are put into super computers as initial conditions. Assumptions and approximations are made about how the atmosphere will behave. The computers then run millions of mathematical equations, and the output is a numerical weather

Prepare your own racing forecast

Check out this link to a video Chelsea recorded about how to make a forecast for your next race.

Weather Strategies for High Performance Sailing

*Chelsea's online weather course is 'designed to bring you actionable sailing strategies using expert weather knowledge.' Click **here** to get more info or take the course.*

Chelsea's **SEA-TACTICS** Website

Chelsea steering upwind in a dying seabreeze, looking for a possible shift toward the gradient wind direction.

Join a free webinar about this issue!

Dave is now doing a free webinar (for subscribers only) after the publication of each issue of *Speed & Smarts*. The webinar for this issue will be held on **Wednesday, February 17, 2021 at 8:00 pm EST** (GMT -5). Dave and Chelsea will both be online to explain the concepts in this issue in greater detail and to answer your questions. The session will go for roughly 75 minutes and then a link to watch the replay will be: 1) sent to everyone who registers; and 2) posted on the *Speed & Smarts* website. This webinar is free, but registration is required.

Webinar Topic: S&S Issue 151 - Wind Strategies

Date: Wednesday, February 17, 2021 8 pm EST

Register here *(This is required in order to get a Zoom link and a link to the replay afterward)*

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Speed & Smarts is published bi-monthly (roughly).

Check out Dave's webinar schedule here.

Replays of past webinars are for sale here.

We'd love to get your feedback!

We do a survey after every webinar, but it's been a long time since we asked for your comments about *Speed & Smarts*. Here is your chance to tell us what you like and don't like about this newsletter. Your feedback will be very valuable going forward with digital issues, webinars and so on. Thanks for your help!

Link to Survey

Get the *Wind Strategies* Webinar!

*Dave and Chelsea recently did a four-part webinar about all of the topics in this newsletter (and more!). If you're eager to learn about weather and wind for racing sailors, you'll enjoy this webinar series. The replay includes 6 hours of content which you can watch as many times as you want. S&S subscribers get **20% off** the purchase price by using this coupon code at checkout: WRZ20*

Click here *to buy/get info.*

A Four-Part Webinar Series

Wind Strategies

Dave Dellenbaugh/Chelsea Carlson

An in-depth look at wind pressure and shifts from meteorologic and strategic perspectives.

Part 1: **Puffs & Lulls A: Weather**

Part 2: **Puffs & Lulls B: Racing**

Part 3: **Wind Shifts A: Weather**

Part 4: **Wind Shifts B: Racing**

REPLAY: Approx 90 minutes each; 6 hours total

Price: $40 Includes free study materials and unlimited access to the replay of each session.