



Winds

by **David Morgan-Mar**

Our weather is controlled by the sun. It also depends on local geography to refine the details. Here, the most important thing is whether the local region is land or sea. After that, the details of sea temperature or the topography of the land come into things as well. But the large patterns of our weather are driven by sunshine.

What the sun does is to heat up regions of the Earth on which it shines. If it weren't for the sun, Earth would be a frozen ball, covered in a thick layer of ice. The sun provides enough heat to keep most of our water molten. The temperature of most of the water in the world is still very cold

— far too cold to go comfortably swimming in. The sun only warms water appreciably in tropical and subtropical regions, and then only in a shallow surface layer. Fortunately for swimmers, it's the shallow surface layer we like to swim in, whether that be in the ocean or in lakes or rivers.



Sun shining on land and water.

So the surface temperature of the ocean varies across the globe. The land also absorbs the heat of the sun, and it does it *better*, in the sense that the land gets hotter faster than the ocean does. This is because of the property known as the **specific heat** of substances.

Specific heat determines how much **heat energy** is required to bring about a certain rise in temperature. You might think that this should always be the same (add X amount of thermal energy, get Y degrees of temperature rise), but in fact it depends on the substance being heated, and in a non-intuitive way. Things like metal and rocks tend to heat up fairly quickly. Put a rock into a hot oven, and it will heat up to match the oven temperature in a certain amount of time. Put the same mass of water (in a dish), or even the same volume of water (which is smaller) into the oven, and it will take a longer time to heat up. Water actually requires *more energy* to heat up for every degree of temperature than the same mass (or the same volume) of metal or stone. We say that water has a higher specific heat than the other substances.¹

What this means is that if the sun shines on land and on water for the same time, the land heats up *faster* and heats up *more* than the water does. The converse of this is that at night, when the sun is absent, the land cools down faster and cools down more than the water does. One immediate effect this has on weather is that coastal regions tend to have milder weather than inland regions. The land heats up by day and cools down by night, but the presence of a large body of water next to coasts has a moderating influence, keeping the air temperature over the adjacent land cooler in the day and warmer at night. This is why inland regions generally have more extreme temperatures than coastal areas.

Another effect this difference has is on winds. Hot air tends to rise — this is the principle behind the hot air balloon. During the day, land tends to heat up, causing the air to be less dense. If there is local variation in the temperature, the air will rise in the warmer regions and fall in the cooler regions to take its place. One form of local variation can be provided by a coastline, as the air over the sea will be cooler during the day. The result is that on warm afternoons the air rises over land, and sinks



Sea breeze time.

over the sea. To replace the air over the land, a cool breeze begins to blow inland from the ocean. We call this a **sea breeze**, and you will experience it if you ever spend a fine day in a warm, sunny coastal location. Higher in the atmosphere, away from our notice down on ground level, the air completes a circuit by blowing back out to sea, where it sinks and starts the cycle again. These sorts of vertical circuits driven by differences in temperature are called **convection cells**.

At night, the water retains its temperature better than the land. Its high specific heat means it has to lose more thermal energy than the land for a similar temperature drop, so it takes longer to cool down. When the land surface temperature drops below that of the sea, the air circulation starts to reverse, rising over the now warmer sea and sinking over the land. This

causes a breeze to blow out from the land towards the sea, called a land breeze.

Large scale weather is caused by similar effects operating over wider areas.

Generally speaking, the sun tends to cause tropical regions near the equator to warm up more than areas closer to the poles. This sets up a more or less steady circulation of air, rising near the equator and sinking back down at higher latitudes. Because of issues of stability of large scale motions of the atmosphere, this does not form a single large convection cell of air rising at the equator, blowing towards a pole, sinking near the pole, and blowing all the way across the surface back to the equator. The circulation actually breaks up into smaller cells of air movements.

Air rising near the equator tends to start sinking again by the time it reaches

about latitude 30° north or south.

These cells (one either side of the equator) are called the **Hadley cells**, after the English meteorologist **George Hadley**. There are similar cells in each hemisphere with air rising at about 60° and sinking close to the poles, called the **polar cells**. In between these, the air sinking around latitude 30° and rising around 60° drives surface winds which blow from the lower latitude to the higher one, *in spite of* the fact that temperatures around 30° latitude tend to be warmer than at 60°. Air movements in these middle latitude regions are effectively dominated by the combined stronger air movements of the equatorial and polar regions. These cells are called the **Ferrel cells**, for the American meteorologist **William Ferrel**.

The next complication is caused by the fact that the Earth rotates. In the northern hemisphere, as you travel



The Earth spins on its axis, complicating wind movements.

north you are also moving closer to the axis of Earth's rotation. When you are on the equator, the spinning of the Earth once per day means you are actually moving east at a speed of roughly 1700 km/h, measured relative to the centre of the planet. If you stood still at the North Pole, you'd be spinning around your vertical axis once per day, but not moving.² In between, you are moving east at intermediate speeds. Now, if you are travelling north, then you have more eastward speed than you need as you get further north. The result is that you tend to drift to the east. Conversely, if travelling south, you have less eastward speed than you need to keep up with the Earth's rotation closer to the equator, and you tend to drift to the west. In the southern hemisphere, the directions are reversed, you tend to drift west as you travel north, and east as you travel south.

These tendencies to eastward or westward drifting are weak. You don't notice them if you're walking north, or even driving at speed, since the friction you have with the ground is more than enough to keep you moving straight. Winds in the air blow much more freely and over great

distances, and their directions are shifted substantially by this effect, which is called the **Coriolis effect**. The result is that the surface winds caused by the convection cells do not blow directly north and south, but are deflected: northward winds deflected east and southward winds deflected west in the northern hemisphere, and vice versa in the southern hemisphere. You can see the resulting circulation of wind patterns at ground level in Figure 1.

This general pattern of winds was well known hundreds of years ago to people for whom knowledge of the wind was vitally important: sailors. As the European powers of the 15th century began exploring the wider world in large sailing ships for the first time, they quickly discovered that some directions were easier to sail in than others. To travel west from Europe, one had to first head south towards Africa, where the winds would tend to blow to the west. At the latitude of Europe, winds tended to blow from the west, towards the east. This could be used to return to Europe from the Americas, but not travel westward. For similar reasons, travel to South Africa could not be done straight down the coast

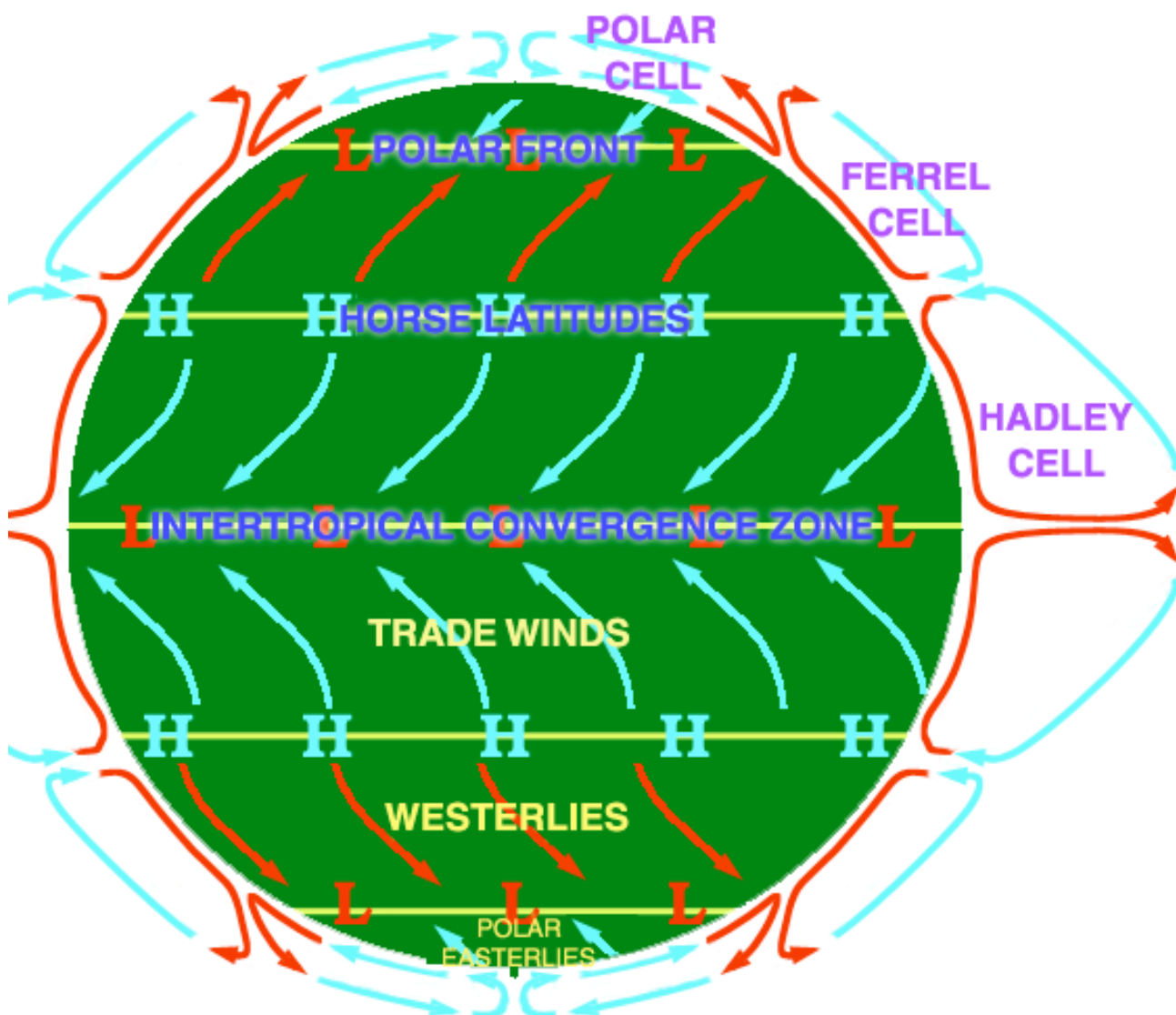


Figure 1: Wind circulation on Earth. [Creative Commons Attribution-Share Alike image by Wikimedia user DWindrim from Wikimedia Commons.](#)

of Africa as you might expect. The winds blew in exactly the wrong direction. To go from Europe to South Africa, you had to sail west towards Brazil, then south down the coast of South America until you reach the latitude of southern Africa, before finally turning east and heading back to Africa.

The winds of the northern Hadley cell blow south-west, and the southern Hadley cell blows north-west. This makes sailing to the west easy in the tropics, but sailing to the east difficult. Fortunately, the Ferrel cells blow in the opposite directions, to the northeast in the northern hemisphere, and to the south-east in the southern hemisphere. The easterly winds of the Hadley cells (winds are named for the direction they

blow *from*, so an easterly wind blows from the east, to the west) became known as the **trade winds**, as they enabled the burgeoning new trade routes of the growing European empires. The westerly winds of the Ferrel cells became known simply as the **westerlies**.

These wind patterns made travel to certain parts of the world easier or



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How does he find the time to do all this?

I have extremely little spare time. I am always lamenting how I don't have enough time to do all of the stuff I want to do. What I do have is a creative urge. Ideas. The desire to make things, and do things, and learn things. What I have is a list of ideas for things I want to do, or make, or places I want to go. A big list. A really, really big list. I can't possibly do them all.

What I also have is the burning desire to make sure I damn well do at least some of the things on that list. I can't sit still in front of the TV. I'm always thinking about what cool thing I could be doing instead. So I'll run off in the ad breaks and fiddle with my photos in Photoshop, or write snippets of dialogue for comics, or bake some banana muffins. Despite not having enough spare time, I make the time to create things, because I can't bear the thought of not creating things.

People who are going out of their way to find the time to be creative and to make new things are taking steps to make something concrete out of the ideas and projects and creative desires locked inside their heads that other people would otherwise never get to see. They are making the most of their time. Go out and make the most of yours.

more difficult, thus shaping the expansions of the European powers. They provide powerful examples of how the quirks of geography can exert a major influence over human history and politics. One particular effect of the wind patterns was that travel between Europe and the new colonies in the Americas necessarily involved a close pass by Africa on the way west. This enabled what became known as the **triangular trade**. Ships leaving Europe would carry relatively cheap trinkets and weapons as cargo. These would be traded to African rulers and European merchants in exchange for slaves. The slaves would then be carried west to the Americas on the trade winds, and exchanged there as labour to work on plantations producing goods desired in Europe: sugar, cotton, tobacco, and spices. These would then be carried to Europe on the westerlies and sold for huge profits.

The Earth's large scale wind patterns are affected on smaller scales by the planet's geography, making what we consider to be the weather. But I think that's all I have time to write this week (I have been a bit busier than usual), so I will continue another time.

Notes

1. Specific heat refers to mass, but you might think that's cheating since a kilogram of water is larger than a kilogram of rock. (Except some forms of **pumice**, which has air bubbles trapped inside it.) But the specific heat of water is *so much* higher than that of rock, that it still takes more energy to heat a cubic metre of water than a cubic metre of rock by the same temperature rise, even though the rock is much more massive.
2. We are all of course also moving around the sun in the Earth's yearly orbit, and moving around the centre of our Galaxy as the sun orbits that, but these are not important for today's discussion.